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GUIDED-WAVE TELEPHONY.*

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INTRODUCTION.

CERTAIN discoveries or achievements in the realm of science stand out preëminently as marking the beginning of new epochs in the world's progress. Such was the invention of the magnet telegraph by Morse, the telephone by Bell, the discovery of radio-activity by Becquerel, electromagnetic waves by Hertz, and X-rays by Röntgen; the invention of the audion by DeForest and guided-wave or high-frequency multiplex telephony and telegraphy by Squier.

Prior to General Squier's invention it had been possible to simultaneously transmit several telegraph messages over a single telegraph circuit, and while certain earlier attempts had been made to develop a system of syntonic multiplex telegraphy, it is to the man who is at present Chief Signal Officer of the United States Army that the world owes the invention of a system of communication by which it is possible to carry on as many as ten or more two-way simultaneous telephone conversations over one electrical circuit. In 1910 Major General Squier (then Major), by a bold and ingenious adaptation of the fundamental principles and appa-

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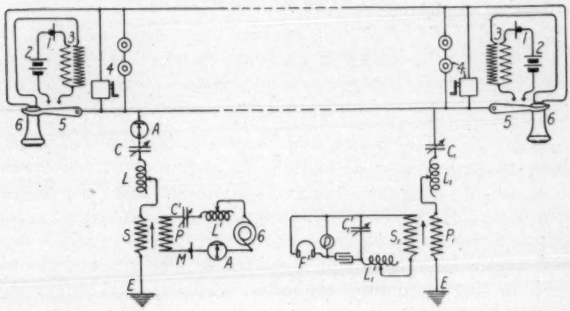
ratus previously employed in radio-telegraphy and telephony, developed the multiplex system which bears his name, and thereby established a distinct branch of the art of communication.

PRINCIPLES INVOLVED.

The fundamental principle underlying the Squier system of multiplex telephony is that of high frequency electrical resonance. Previous attempts to solve the multiplex problem had been based, largely, on electro-mechanical resonance.

Figs. 1 and 2 are reproduced from Squier's original disclosures. Fig. 3 is a simplified diagram illustrating the funda-

FIG. 1.



mentals involved. A source of continuous high frequency electromagnetic waves of definite frequency are impressed upon the physical circuit by means of the air core resonance transformer $L_1 - L_2$. By means of the variable condenser C_1, the circuit consisting of the two parts of the line and the bridging elements just referred to is brought into electrical resonance with the impressed high frequency E.M.F.

Referring to the well-known relation

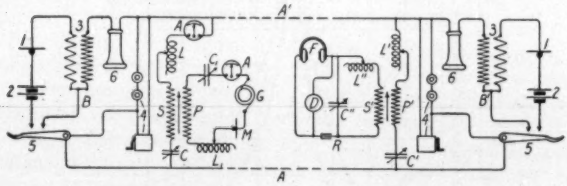
$$I = \frac{E}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

it is evident that the current in the line will be a maximum when resonance obtains; that is, when the inductive reactance equals the

capacity reactance or $\omega L = \frac{1}{\omega C}$. This condition will be indicated by the reading of the ammeter A. Fig. 4 shows two typical resonance curves made from data secured in actual engineering practice.

In Squier's original investigations the source of high frequency energy (see Figs. 1 and 2) was a high frequency alternator.

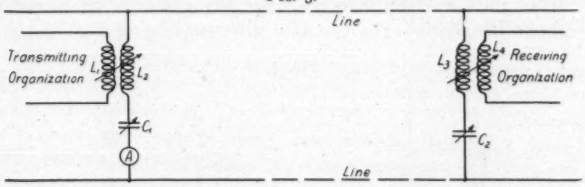
FIG. 2.



The impressed energy was voice modulated by means of an ordinary microphone, thus giving rise to a modulated high frequency "carrier wave" in the physical line.

To detect and translate this "carrier wave" at the receiving end of the line, a circuit arrangement similar to that shown at the right of Fig. 3 is employed. The local receiving organization is

FIG. 3.

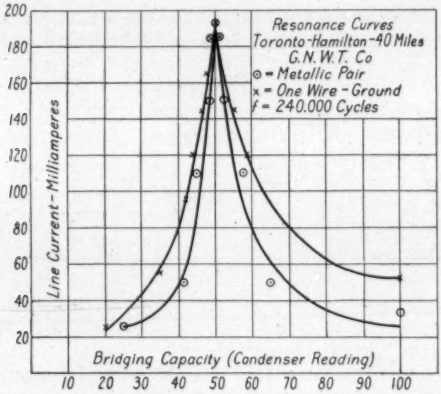


inductively coupled to the line through the air core resonance transformer $L_3 - L_4$. In adjusting the receiving equipment to abstract maximum energy from the line the bridging elements L_3C_2 are adjusted to resonance with the frequency of the carrier wave and the local translating circuit is likewise adjusted to resonance with circuit L_3C_2.

The voice current is recovered from the modulated carrier wave by means of a primitive audion hook-up as shown in Fig. 5.

This will be discussed in detail later. At this point it suffices to note that the receptor is an integrating translator, which delivers to the telephone receiver a varying unidirectional current corre-

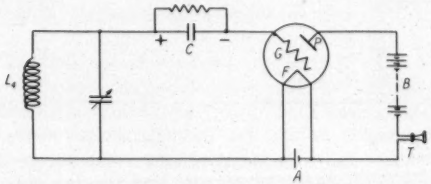
FIG. 4.



sponding to the voice current supplied to the modulating device at the transmitting station.

It is thus evident that we have the elements of a radio-telephone installation, the essential difference being that in place

FIG. 5.



of the connections to earth and the usual antenna, we have, in this case, connections to the two wires constituting a physical pair. The two fundamental factors, then, in the Squier system of multiplex are *the utilization of electrical resonance and the use of an integrating translator*. Whether the frequency of the carrier

current is low or high does not modify the basic principles involved. In this system electromagnetic waves of predetermined length are guided by the metallic circuit, instead of radiating in all directions from an antenna. While there undoubtedly is a certain amount of radiation from the physical line, the over-all efficiency of the guided-wave system is obviously materially higher than in the case of a free-wave system. This is thoroughly confirmed by experience.

DELAY IN PRACTICAL APPLICATION.

Following the original disclosures by General Squier, the author, and doubtless others, began the study of this new method of communication. During 1913–15 the writer conducted a series of guided-wave telegraphic tests over the telegraph lines of the Chicago, Milwaukee and St. Paul Railway and the Delaware, Lackawanna and Western, employing damped-waves and comparatively crude equipment. These experiments established the fact that guided-wave telegraphy over practical distances between stations, and between stations and moving trains, was possible. Telephony by this means was not attempted because equipment for producing undamped waves was not available.

Indeed one of the principal factors which tended to delay [1] the practical application of this new system was the nature and cost of the power unit. The inventor in his original investigation had at his disposal one of the two high frequency alternators existing on this continent.

This, however, was not the only reason why the Squier system of multiplex did not come into commercial use until a comparatively recent date.

A paper by General Squier describing in detail the original investigations connected with his invention was read before the Chicago meeting of the A.I.E.E. on June 28, 1911. This paper was later published as a professional paper of the Signal Corps of the U. S. Army. A critique of this paper by Doctor Jewett, Chief Engineer of the A. T. & T. Co., and others, also appeared in the issue of the Proceedings of the A.I.E.E. which carried the original paper by the inventor.

In his criticism of the Squier method of multiplexing Doctor

[1] Squier's U. S. patents are dated Jan. 3, 1911.

Jewett took the position that the use of a carrier wave of comparatively high frequency would be impracticable owing to the extremely great attenuation which would obtain. We shall refer in a later paragraph to Doctor Jewett's comments. It suffices here to say that it is more than probable that the adverse criticism by so eminent an authority in the telephone art as Doctor Jewett effectively served to discourage, for a considerable period of time, those who might otherwise have been inclined to give practical application to General Squier's invention. Subsequent events have clearly shown that this criticism was not well founded. Indeed the system of multiplex developed by General Squier is understood to be at the present time in commercial use by the A. T. & T. Co. and is being rapidly extended by this and other commercial interests throughout the world.

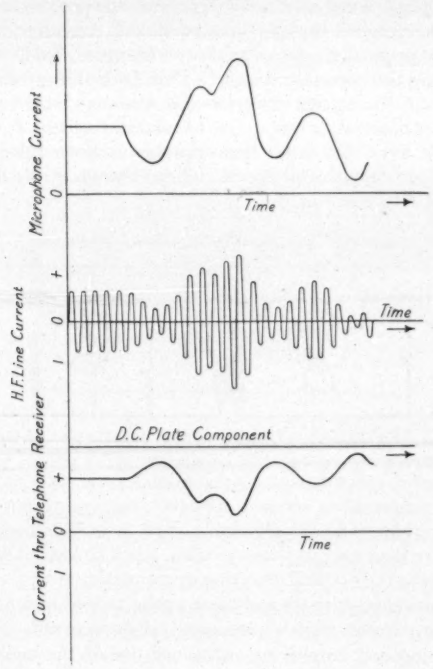
THE THREE-ELECTRODE TUBE AND ITS RELATION TO MULTIPLEX.

Reference has been made to the nature of the source of high frequency current originally available. Owing to the exigencies of the war, the audion, invented by Doctor Lee deForest, came into wide use in the radio art as a detector and amplifier. It also came to be extensively used as a source of high frequency alternating current, and as a modulator of such currents. As before indicated, the invention of the three-electrode thermionic tube marked an epoch in the art of communication, and the development and perfection of this device as a simple and inexpensive generator of high frequency alternating currents made possible the wide practical application of the Squier system of multiplex.

In order to clearly outline current engineering practice in this new art it is necessary to briefly review certain fundamentals connected with the audion, or three-electrode thermionic valve. Recalling the well-known characteristic of such tubes, *viz.*, that only negative charges (electrons) pass from the filament F (Fig. 5) to the plate P, it is obvious that any negative charge on the central electrode will tend to diminish to migration of electrons from F to P. In short, if the grid G is caused to vary in potential the current in the circuit $P\ B\ T\ F$ will vary in a corresponding manner. Further, if the tube forms part of an organization, as shown in Fig. 5, and an alternating E.M.F. is developed in the inductance L_4, the condenser C will become charged as shown. It is thus

evident that the audion is an integrating device. If an alternating E.M.F. of varying amplitude be developed in the inductance L_4 by associating said inductance with the bridging inductance L_3, as shown in Fig. 3, the audion [2] will serve to integrate and trans-

FIG. 6.



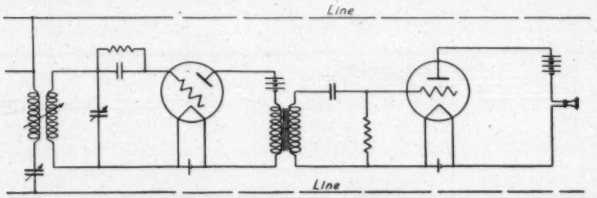
late the carrier wave into a varying unidirectional current in the circuit containing the telephone receiver T, Fig. 5. This process is graphically shown in Fig. 6. It is seen from the last curve in the figure that the current through the receiver corresponds to

[2] It is probable that General Squier was the first to use the audion in connection with speech or telegraphic transmission over physical circuits.

the envelope of the line current. In this manner the voice current is "recovered" from the high frequency carrier current which is guided by the physical circuit.

From the foregoing remarks regarding the audion it is evident that the device is inherently a repeating and an amplifying agent. Since the plate circuit accurately reproduces the potential variations in the grid circuit it thus becomes possible to magnify or amplify the energy originally supplied to the grid-filament, the local battery B supplying the necessary energy. Thus if the mean value of the amplitude of the carrier current is too small to give a tone intensity of commercial value in the telephone receiver T, we may arrange to have the output from the first detector tube feed the grid-filament circuit of a second audion through a suitable transformer as shown in Fig. 7.

FIG. 7.

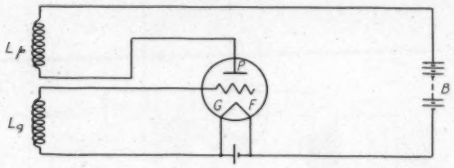


If greater magnification is required several such amplifying tubes are connected in series. However, because of various electrical disturbances in the physical circuit, it is found impractical to use more than two amplifying tubes, when connected as shown, in addition to the original detecting or translating tube.

It is, however, with the audion as a generator of high frequency alternating currents that we are principally concerned. Recalling the repeating and amplifying characteristics of the audion, it is easy to see that conditions may be so arranged that the plate circuit will react upon the grid circuit and thus automatically effect a variation in current in the plate circuit itself. Referring to Fig. 8, if an inductance L_p, for example, be inserted in the plate circuit any variation in the potential of the grid will, as before indicated, result in a variation in the current in the plate circuit and hence a change in the potential at the terminals of the in-

ductance L_p. Since L_p and L_g are inductively associated, this potential variation in L_p will cause a corresponding variation in L_g, and hence in the potential of the grid. This change will again cause a change in I_p, which will again react to cause a change in E_g. It is thus evident that there has been initiated an electrical cycle of operations which tends to repeat itself indefinitely, the energy necessary to sustain this cycle being derived from the battery B. The cycle usually starts automatically with the closing of the filament circuit. The frequency of the cyclic process is governed by the value of the inductances in the plate and grid circuit and any associated capacity. In short, the audion thus becomes a source of alternating current, energy being abstracted from the audion organization by associating with it an independent resonant cir-

FIG. 8.



cuit (see Fig. 10) or by electrostatically coupling to an energy-absorbing system. The simplicity and constancy of such a source of alternating current makes guided-wave telephony a practical every-day accomplishment.

Not only does the audion act as a generator of high frequency alternating currents and a detector of the same, but it may also functionate as a modulating device.

Speaking broadly, there are three general methods of utilizing the audion for the purpose of impressing the ordinary microphonic voice current upon the high frequency carrier current.

One of the most commonly used arrangements for accomplishing this is shown in Fig. 9.

This circuit is variously called the "choke coil," "constant current" and "Heising" method. By referring to Fig. 9 it will be noted that there are two tubes in parallel, the plate voltage being supplied by a D.C. generator or rectifier unit. The power tube OVT, together with the associated circuit $L_3C_2L_4$, constitute the

high frequency oscillating circuit. The air core choke L_2 prevents the high frequency current from passing back through the generator and modulating units.

The tube MVT, and the associated microphone M and transformer T, form the modulating unit. If the microphone M be spoken into an alternating E.M.F. will be developed in the secondary of the transformer T, the wave form of this E.M.F. corresponding to the upper curve in Fig. 6. The grid, or control electrode, of the modulating tube is thus subjected to a varying potential. As previously pointed out, this will result in what amounts to a variation in the internal resistance of the modulating tube MVT. Therefore, the current passing through the tube between the

FIG. 9.

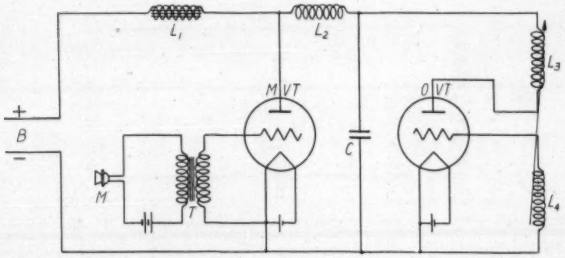
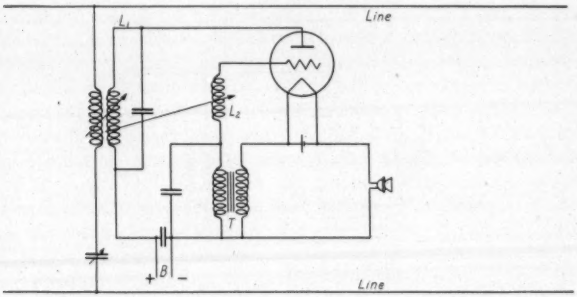


plate and filament will vary in a corresponding manner. Because of the presence of the choke coil L_1, the total current drawn from the D.C. generator cannot change rapidly, and since the two audions are in parallel, it follows that if the current through the tube MVT increases, that through OVT must decrease, and *vice versa*. Thus the power supply to OVT will be modified in conformity with the voice current impressed upon the modulating tube. It therefore follows that the output of the oscillating power tube will likewise vary, and thus the carrier wave emitted by the circuit $L_3C_2L_4$ will vary in amplitude, or, as it is usually expressed, be modulated. This method of modulation is very satisfactory for units of small output, but possesses the disadvantage that at least two tubes are required.

A second method is known as "direct grid" modulation. A

circuit operating on this principle and which gives good results in guided-wave practice is shown diagrammatically in Fig. 10. In this case the microphone is coupled through the modulating transformer T directly to the grid of the oscillating power tube. The potential of the grid will thus be caused to vary in conformity with the microphonic voice current, and the power output of the tube will vary in a corresponding manner. With the particular circuit shown the completeness and accuracy of the modulation of the emitted carrier wave is largely determined by the mutual inductance between the plate and grid coils L_1 and L_2. The method of modulation just outlined possesses the advantages that

FIG. 10.



but one tube is required, and that the modulation may be easily adjusted.

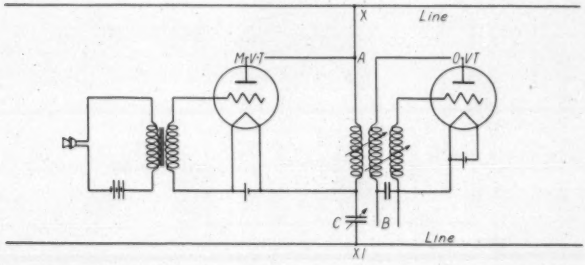
The third general method of utilizing the three-electrode tube as a modulating agent is shown schematically in Fig. 11. In this organization the plate circuit of the modulator tube is connected as a shunt to a part or all of the secondary or bridging inductance L. The variations of the grid potential effected by the associated microphonic circuit causes the modulating tube to act as a variable resistance in parallel with this inductance and thus tends to functionate in part as an energy absorbing agent and in part as a detuning device. The result is that the energy supplied to the line by the oscillating tube is caused to vary in accordance with the original microphonic current.

This system possesses the disadvantage that at least two tubes

are required and also that the modulation is more or less incomplete thus resulting in a comparatively low value of tone intensity at the receiving end. Incidentally it may be added in this connection, that a more satisfactory "absorption" arrangement in guided-wave practice is to insert the microphone itself directly in the bridging circuit, either between X and A or between C and X_1.

From what has been said in outlining the behavior of the three-electrode tube as a detector, an amplifier, an oscillator and a modulator, the present method of accomplishing high frequency multiplex telephony is more or less obvious. We may, for example, bridge across a physical telephone or telegraph pair or between a single wire and the ground, several transmitting organizations

FIG. 11.



similar to that shown in Fig. 10, each transmitting unit being permanently adjusted to deliver to the line a voice modulated high frequency current of a definite and fixed periodicity. At the receiving end of the line a corresponding number of receiving units, similar to that shown in Fig. 7, are bridged across the same physical circuit. Each receiving unit is "tuned" or brought into electrical resonance with a certain transmitting set. Speech may then be carried on over any one or simultaneously over all of these super-channels. Each party to a conversation utilizes a carrier frequency, two such frequencies being required for a two-way conversation. When the carrier waves are properly selected there is no mutual interference or "cross talk" between the super-channels; neither are the guided-wave conversations heard in the ordinary physical telephone apparatus, and the transmission over the physical circuit is inaudible in the multiplex equipment.

NUMBER OF SUPER-CHANNELS.

The maximum number of two-way guided-wave channels, which may be simultaneously operated over a single physical circuit, depends somewhat upon the electrical constants of the particular line and also upon certain inherent limitations of the multiplex system itself.

It was noted above that two carrier waves are usually employed for carrying on a two-way conversation. As a result of the well-known principle of interference, if two alternating currents coexist in a physical circuit, there will also obtain a third alternating current whose frequency will be equal to the numerical difference between these two original frequencies. If the two primary frequencies are near enough together, the resulting "beat" frequency will have a value which, if the resultant current reaches the receiving apparatus, will manifest itself as a high-pitched note. In short, an electrical "beat tone" will exist, and, unless eliminated by means of elaborate electrical filters, will prove to be a disturbing factor in the guided-wave telephonic transmission. When it is recalled that the average human ear can begin to sense a tone when its frequency is not greater than 20,000, it will be evident that the frequencies of the two-carrier waves utilized for a two-way conversation must differ by at least 20,000. For example, if one-carrier frequency is 100,000, the other carrier frequency must either be 80,000 or 120,000.

Further, it will also be obvious that the lowest carrier frequency which can be used must be greater, theoretically at least, than this upper limit of audition, *viz.*, twenty thousand. In practice, however, it is found that a fundamental carrier frequency of about 15,000 may be used.

The upper practical limit of carrier frequency has not yet been definitely determined. As before indicated, it was maintained by those who originally attempted to point out the limitations of this system of communication that, owing to supposed attenuation effects, frequencies of the order of 100,000 would be entirely impracticable. The engineering research of the Signal Corps and of the writer has clearly demonstrated that frequencies of the order of 500,000 are entirely practical. There is reason to believe that frequencies as high as one million per second may possibly be utilized in multiplex practice.

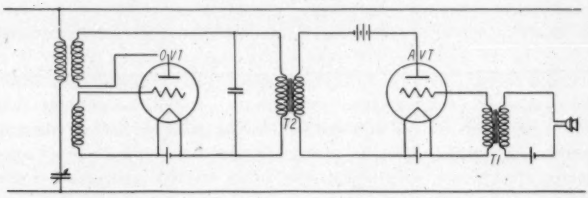
However, as a basis of discussion, if we take the limit as

15,000 and 500,000, respectively, and remember the further limitation imposed by the possibility of "beat notes" between the fundamental carrier frequencies or between the first harmonic of one carrier wave and the fundamental of the next, it follows that at least six simultaneous guided-wave two-way conversations are entirely practicable over a single physical circuit—and this in addition to the usual two-way telephone or telegraph traffic.

It, therefore, follows that we have here a system of communication which makes it possible to increase the telephonic traffic-carrying capacity of a given line at least sixfold, and, when distances of the order of 100 miles or more are considered, at a cost substantially lower than that necessary to construct and maintain additional physical lines.

There is reason to believe that the number of high frequency

FIG. 12.



multiplex telephone channels that may be superimposed upon a single physical circuit may, in the near future, be doubled.

It is possible to arrange a circuit of such a character that it will deliver high frequency currents to the line only when conversation is taking place.[3] With such an arrangement both parts of a two-way conversation could take place on carrier waves of the same frequency; in fact, true duplexing would obtain. Therefore instead, for example, of six simultaneous two-way conversations it would be possible to establish twelve super-channels. A circuit which is said to accomplish this end is shown in Fig. 12.

By reference to the figure it will be noted that the voice current is amplified by the tube *AVT*, and that the plate circuit of this amplifying tube supplies energy to the primary of the audio-

[3] See General Electric British Patent No. 15,237–1915. Also "High Frequency Multiple Telegraphy and Telephony on Wires," by H. Fassbender and E. Habann, *Jabrh. d. Drahl, Tele.*, Oct., 1919.

frequency transformer T_2. The secondary of this transformer serves as a source of anode potential for the oscillating power tube *OVT*. It is thus evident that the high frequency power circuit will not deliver energy to the line except when sound waves impinge upon the microphone.

The author has designed a circuit of such a nature that the tube which acts as a high frequency oscillator will also serve as a detector, thus making it possible to utilize the same tube for both transmission and reception.

This step has been made possible as a result of the discovery by the author that it is possible to design a circuit of such a nature that it will oscillate without any "*B*" potential, in the commonly accepted sense of the term. Further, this new circuit may be so adjusted that the "regenerative" state will obtain, thus making the organization highly sensitive as a detector.

By properly associating a microphone and a telephone receiver with this new circuit, it has been found possible to design an organization such that one tube functionates as both oscillator and detector, and further that no energy is delivered to line except when one speaks into the microphone.[4] While the engineering development work on this new circuit has not reached the point where equipment is manufactured on a commercial scale, yet the result of the experimental work this far carried out justifies the statement that it is possible to design a practical multiplex telephone unit of comparatively small size, and which will serve to double the number of high frequency multiplex conversations which may be simultaneously carried on over a single physical circuit.[4]

In considering the question of the maximum number of super-channels between any two points, the problem arises concerning the utilization of adjacent physical circuits on the same pole lead. Experience has shown that under certain conditions there is no cross-talk between adjacent parallel super-channels, while under other conditions cross-talk will obtain. It has been found that excessive transpositions are unnecessary. It is therefore possible to operate high frequency super-channels over adjacent parallel physical circuits. If traffic conditions are such that it is unnecessary

[4] The author gave a practical demonstration before the Institute of a two-way conversation by means of his newly designed circuit.

to utilize more than one physical circuit on a pole lead as a basis for super-channels, and conditions are such that high frequency cross-talk occurs between adjacent metallic circuits, the natural procedure is to electrostatically connect the several physical pairs in parallel through the high frequency bridging circuits, thus collecting and utilizing a part of the energy which would otherwise be wasted.

CONDUCTORS WHICH MAY BE USED.

In considering the utilization of the various metallic circuits which may serve to guide the high frequency carrier currents, we come to a consideration of the effect of the material constituting the physical circuit.

Experience has shown that copper, copper-clad iron, and aluminum wire may be used. It has been found in practice that solid copper and copper-clad conductors of equal surface area have practically the same conductivity and hence serve equally well as guiding media for high frequency carrier waves. Ordinary galvanized iron wire, however, will not answer. It has been found, for example, that twelve miles of No. 12 galvanized iron telephone wire will completely obliterate all resonance effects, and that it is not possible to effect a transfer of energy unless frequencies of the order of 20,000 are employed. These practical results are consonant with the effects which may be predicted from theoretical considerations. Preuner and Pungs[5] have shown by measurements that the zinc coating on iron wire must be substantially thicker than that of a copper exterior to effectively shield the iron core.

It is of both theoretical and practical interest to find that high tension power lines may be utilized as guides for high frequency carrier waves, and without any interference to multiplex telephonic transmission from the low frequency power currents.

In making use of a power line to establish guided-wave telephone service, the high frequency equipment is electrostatically coupled to the power line by suitable high tension condensers or by connecting directly to a wire of a few hundred feet in length, supported parallel to and within a few feet of the power wires and thence to earth. A system employing the first method has

[5] "Electro-plated Iron in High-Frequency Fields," by G. Preuner and L. Pungs, *Verhandlungen der Deutschen Physikalischen Gesellschaft*, Sept., 1919.

been in practical operation in Japan [6] for more than a year. An installation [7] utilizing the second plan mentioned is in use in Germany. The practical utility of this aspect of guided-wave communication is obvious.

FUNCTIONING OF A PHYSICAL CIRCUIT AS A H.F. CARRIER.

In considering telephonic transmission by means of carrier currents the general behavior of physical circuits as high frequency channels becomes of prime importance.

One of the first factors which commands one's attention is the fact that in high frequency work a physical line acts as a lumped capacity. In other words, at radio frequencies the line reactance is in the nature of a capacity instead of an inductance. There is abundant evidence of this. The capacity of a 100-mile No. 10 aerial telephone pair is approximately 0.8 M.F., and this line capacity is in series with the bridging inductance and capacity of the connected h.f. unit. Since the latter has a value of the order of 0.001 – 2 M.F. the bridging circuit should act when connected to the line as though shorted by a condenser of relatively large value. Such is found to be the case in practice. The setting of the bridging condenser is the same whether the apparatus is connected to a line fifty miles or several hundred miles in length.

Indeed, it has been observed that a transatlantic cable will give practically the same resonant setting on the bridging condenser as will a circuit of a few hundred feet in length. Further, since the change in capacity due to a difference in the size of line wires is small compared with the total capacity of a line, and since as shown above, the line capacity is in series with the h.f. bridging capacity, it will not appreciably alter the tuning of the g-w. telephone set if it becomes necessary, owing to operating conditions, to connect the h.f. equipment to various metallic circuits. The resulting element of practical operating flexibility is thus apparent.

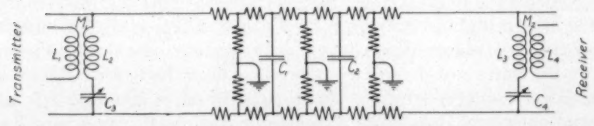
In General Squier's original paper, before referred to, the conclusion is reached that the line reactance is in the nature of an inductance, rather than of a capacity. That conclusion was reached because the capacity reactance of the bridging condenser

[6] "Simultaneous Transmission and Reception in Radio Telephony," by Noboru Marumo, *P. I. R. E.*, Vol. 8, No. 3, June, 1920.

[7] "H. F. Telephony in High Voltage Overhead Power Distributing Systems," by Gewecke, *Elektrotechnische Zeitschrift, 41,* Aug. 26, 1920.

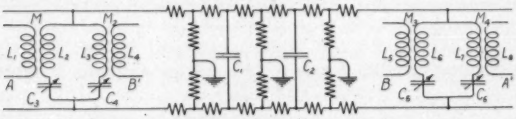
at resonance exceeded as computed, the inductive reactance, and since at resonance the capacity and inductive reactances should be equal, it was thought that the line reacted in such a manner as to supply the difference. There appears, however, to be an error in the above point of view. Mutual inductance undoubtedly existed between the coupling inductance P and S, Figs. 1 and 2, in General Squier's organization. Hence in computing the inductance value the mutual inductance should have been considered.

FIG. 13a.



In dealing with the inductance and capacity factors, the line as a whole must be considered. The line organization appears to resolve itself into two resonant circuits having electrostatic coupling. Fig. 13*a* probably represents the several factors (except radiation resistance) as they obtained in General Squier's original experiments, and Fig. 13*b* as they obtain in a simple case in actual g-w. practice. In the latter Fig. *A* represents a transmitting unit and A_1 the corresponding resonant receiving unit; *B*, the second trans-

FIG. 13b.



mitter, and B_1 the corresponding receiving organization. So far as the g-w. organizations at the left of the figure is concerned, the first mile or less of the physical line determines the effective line capacity C_1, and in a corresponding manner C_2 is related to the coupled system at the right.

As additional experimental proof of the above tentative theory regarding the functioning of a physical circuit as a high frequency channel, it may be noted that the physical line may be "dead shorted" at some point between the two terminal stations without interrupting commercial conversation on the h.f. channel. Fur-

ther, if the bridging circuit of a given transmitting set is adjusted to give maximum line current, and the tuning of the receiving organization, including its bridging circuit, be changed, it becomes necessary to readjust the transmitter circuits in order to maintain a resonant condition with the line.

INTERFERENCE.

In discussing the possibilities and limitations of g-w. telephony, the question of interference naturally arises. This point has been partially covered in the discussion concerning the use of power lines as h.f. channels. It may be added in this particular connection that experience has shown that 110,000-volt 25-cycle power lines running parallel to, and at some points within 50 feet of, the physical telephone system, produce no interference whatever in the g-w. super-circuit.

It has also been found that g-w. telephone channels may be successfully operated over a telegraph circuit which is being used for Morse duplex or for duplex printer operation.

There is a possibility of interference from continuous wave radio stations. This may result from the fact that the frequency of the wave, emitted by an undamped radio station, may chance to be near (within about 20,000 cycles) the frequency of a multiplex telephone carrier wave. The physical circuit which serves as a basis for the h.f. super-channels will act as an antenna and thus intercept enough energy to produce a heterodyne effect with the undamped g-w. telephone wave. In short, the effect in the g-w. telephone receiver will be exactly the same as when two g-w. telephone waves combine to form a "beat note," as previously discussed.

Spark radio stations may also be heard in the g-w. telephone apparatus if the carrier wave used has the same value as the wave emitted by the radio station. This is particularly true if a single line wire and earth return is being used for the super-channel.

Since, however, the wave-lengths of all radio stations are known, it is a comparatively easy matter to avoid radio interference, if such exists in any given case, by not using as carrier currents those waves which are near in frequency to the interfering radio wave.

With regard to atmospheric and other irregular extraneous electrical disturbances, commonly spoken of as "static" in the

radio art, it may be said the guided-wave system is no more subject to interference from this source than is the ordinary telephone organization. When utilizing untransposed and poorly insulated telegraph circuits as guides for h.f. carrier waves, the interference due to atmospheric disturbances is naturally more marked than when connection is made to well-constructed telephone circuits. However, interference is, in general, decidedly less marked than in the case of radiotelephony. The author has never experienced but one occasion when communication by g-w. telephony was interrupted by vagrant disturbances in the line, and this was when using a telegraph circuit as a guiding channel.

ATTENUATION AND EFFICIENCY.

In considering the system of guided-wave telephony perhaps the most interesting, and from a purely scientific point of view, the most significant, is the question of the absolute and relative magnitude of the energy required to effect commercial communication by this means.

Let us first compare the over-all efficiency of g-w. telephony with radio telephony. Using one hundred miles, and no extra-detector amplification, as a basis for comparison, we find that experience shows that, when operating under average over-land conditions, radio telephonic communication can be effected if the transmitting apparatus delivers one hundred watts to the radiating system. This gives us a mean energy-distance ratio of one watt per mile.

In the case of g-w. telephony extensive engineering tests have shown that when utilizing a carrier current having a frequency of the order of 125,000 cycles, commercial communication can be maintained if the equipment will deliver five watts to a well-constructed physical telephone circuit consisting of a pair of No. 10 copper aerial wires. This gives a mean energy-distance ratio of 0.05 watts per mile. It will thus be seen that the g-w. system is twenty times as efficient as radio telephony.

In making the above comparison, it was assumed that neither the radio nor g-w. apparatus was connected to local land lines. If connection were made to local physical circuits an additional amount of energy would be required in both cases for the purpose of amplifying the voice currents. As this would be of the same order in each case, and since its value would be a more or less

fixed quantity and independent of the distance separating the h.f. stations, it has been omitted from the comparison.

In passing to a consideration of the comparative efficiency of guided-wave transmission and communication by means of ordinary telephony, we come to the most vital part of our subject. This aspect of our discussion involves the question of attenuation, and again brings before us the original criticism of Doctor Jewett and others.

Doctor Jewett says[8]: "Further, a few simple computations will show that the attenuation of current at the high frequency which must be used in Major Squier's system is enormously greater than the attenuation at the frequencies which go to make up ordinary speech. The phenomena of current attenuation on long telephone circuits are not different in character for frequencies of from 15,000 to 100,000 periods per sec. than for frequencies of from 200 or 300 to 3000 per sec. *and the same attenuation formulas can be used.*" (The italics are mine.) On this assumption, Doctor Jewett then proceeds to compute both the low and high frequency attenuation constants for several sized conductors. Both computation and engineering experience show, however, that the attenuation in h.f. transmission is not of the order indicated by Doctor Jewett's computations. It would appear that a serious error was made by Doctor Jewett in assuming that the standard attenuation formula applies in the case.

It is, however, a matter of experience that frequency *does* enter into the determination of the power-distance ratio. How, then, can this fact be reconciled with the above analytical relation?

In dealing with high frequency currents on physical conductor a certain amount of energy is in all cases *lost by radiation.* There is abundant empirical evidence that such radiation obtains in the case of h.f. carrier waves on telephone and telegraph circuits. Indeed, it has been found possible to establish h.f. telephonic communication between a moving train and a fixed station, the latter utilizing a physical circuit along the right of way as a h.f. wave channel. A part then of the energy originally delivered to the line by the terminal apparatus is lost by radiation.

It is difficult to determine the law of radiation which obtains

[8] Multiplex Telephony—Discussion, by Frank B. Jewett, A. I. E. E., Vol. xxx, Part ii, 1911.

in the case of a physical circuit whose length is many times the wave-length of the h.f. carrier wave. The problem is rendered particularly complex because of the fact that the physical circuit in question may be only one of a considerable number of other metallic circuits on the same pole lead, thus greatly modifying the electrostatic and magnetic field about the conductor.

The dissipation of h.f. energy in a non-transposed telegraph circuit has been found by comparative tests to be very much greater than in the case of a transposed telephone circuit made up of the same sized conductors. There is some evidence for believing that the loss of energy is modified by the number of transpositions in the line. It is possible that a twisted pair would functionate advantageously. This explanation, however, is only tentative, not having been fully established.

In the above discussion reference has only been made to open aerial lines. In the case of cables the dissipation of energy is due to dialectric loss, eddy currents in the cable sheath, and radiation, with the result that the attenuation in cables is somewhat higher than in open lines. The opinion appears to obtain that the attenuation in cables is prohibitive. Practical experience shows that such is not the case. Our experience in working with frequencies up to 500,000 over lines, which included between two and three miles of cable, shows that it is unnecessary to terminate the h.f. super-channel at the end of the open aerial line when establishing h.f. multiplex service between cities.

In addition to the energy lost by radiation, there must also be considered the question of high frequency insulation resistance. Insulation which may have a high value for direct or low frequency E.M.F.'s frequently exhibits low values when h.f. pressures are involved.

Referring to equation 3 above, it is therefore evident that the value to be given to G is at present indeterminate. The relation for h.f. attenuation which is finally evolved will probably contain a term or terms corresponding to G, and which will account for radiation and leakage. This term will undoubtedly prove to be a function of the frequency. Additional data must be at hand before such a working relation can be developed. Progress is, however, being made both analytically and empirically along this line.

The incorrectness of Doctor Jewett's attenuation values are even more strikingly shown when one examines the energy ratios which he evolves.

For instance, he states that 300,000,000 times the energy would be required to telephone by means of a h.f. 50,000-cycle carrier wave for a distance of 1000 miles, over a non-loaded No. 8 B.W.G. copper circuit, than would be required for equal communication by ordinary telephonic means.

If we assume that the energy supplied to the circuit by the regular telephone transmitting organization is of the order of one watt, it is evident, on the basis of Doctor Jewett's assumption, that 300,000 K.W. would be required to effect equally good transmission by the high frequency means.

Now, 50,000 cycles correspond to a 6000-metre wave, and it is a matter of common knowledge that direct radio-telephonic communication can be established when using a wave of this order with the expenditure of an amount of power not to exceed one three-thousandths part of that indicated by Doctor Jewett. In view of the fact that communication by means of h.f. carrier waves is several-fold more efficient than by direct radio, Doctor Jewett's figures are plainly erroneous.

As before indicated, it has been established that when utilizing a carrier frequency of the order of 100,000 cycles, the energy input required in guided-wave telephony does not exceed five watts for the first one hundred miles. Though we do not at present know the complete law relating energy and distance in guided-wave practice, there is evidence for believing that the falling off of energy is not *more* rapid than indicated by an inverse square law. On this assumption it would require a h.f. input to the line of something like 500 watts to cover a distance of 1000 miles, repeaters and extra-detector amplification not being used.

Further, in making the original comparisons of the guided-wave system with ordinary telephone practice, the critics apparently failed to take account of the fact that the audion, which forms an essential part of the Squier system, is inherently an amplifying device, and therefore, does not require as great an energy input from the line as does the ordinary telephone organization. Their original premise was, therefore, incorrect.

Unfortunately, it is not easy to set up artificial high frequency

lines, and thus be in a position to make h.f. transmission measurements in the laboratory. This is due chiefly to the fact that it is difficult to simulate radiation as it exists in guided-wave practice. Progress is, however, being made along these lines and there is reason to expect that important disclosures concerning the laws governing h.f. transmission will be made in the near future. The factor that has tended most to inhibit progress in the high frequency field is our preconceived notions. We have failed to realize that, in high frequency work, we are dealing with phenomena which follow, in many cases, entirely new and unknown laws, and that we are led into serious errors when we attempt to apply laws which obtain in low (audio) frequency practice.

In this general connection the author is reminded of one or two typical instances of traditional scientific beliefs. Several years ago the writer suggested to one of the leading radio physicists that possibly one could abstract energy from the electromagnetic waves employed in radio communication by placing a long horizontal wire just above the surface of the sea. The scientist referred to held that such a system would not functionate as a receiving antenna because it would practically coincide with a surface of good conductivity. We know now that submarine craft communicate by radio when running awash and also when submerged.

During the war the writer suggested to one of the prominent research engineers that possibly the power required to effect transatlantic radio communication could be materially reduced if the ground connections of two such stations were made to the sheath of the same transatlantic cable. It was thought that the cable might serve to guide and confine the electromagnetic waves to a narrow channel rather than allowing them to spread in all directions. The engineer did not concur in the suggestion, basing his arguments upon laws which obtain in the case of direct and low frequency alternating currents.

We are still of the opinion that the suggestion is worth trying.

POWER SUPPLY.

It is now common practice to use rectified alternating current as a source of power for operating the oscillating power tubes which supply the h.f. carrier current to the line. Frequencies as low as twenty-five cycles are successfully employed.

By the use of smoothing inductances and condensers, all trace of A.C. "hum" is eliminated. By the use of such a power unit instead of a motor generator, the guided-wave apparatus can be arranged to respond instantly to remote control. Switching and articulation with local physical telephone circuit is thus greatly facilitated.

USES AND ADVANTAGES.

In the foregoing discussion we have endeavored to point out the limitations of the h.f. multiplex system of telephony, and, incidentally, certain advantages.

In dealing more specifically with the advantages, it is to be noted that, in general, guided-wave transmission gives a more nearly perfect reproduction of the voice than does wire telephony.

In ordinary telephony there are three inherent causes of distortion, *viz.*, the microphone, the telephone receiver, and that due to the line. The first two are, of course, present in the h.f. system. The distortion due to the line is, however, absent. This is evident from the following considerations.

Since the quality or timbre of vocal sounds is due to the presence of overtones, the varying line current in ordinary wire transmission will also have a corresponding complex wave form. In short, when analyzed, this telephonic line current consists of several elemental constituent parts, each component having a different frequency. Since, under a non-resonant condition, attenuation is a function of the frequency, the components of the line current corresponding to the overtones in the voice will suffer different degrees of attenuation, with the result that the wave form will be modified. In ordinary words tonal quality is not faithfully transmitted.

If, in comparison with the process just outlined, it is recalled that in g-w. transmission a h.f. alternating current of a single frequency serves as a carrier wave, and that speech is transmitted by varying the *amplitude* of this carrier wave, it will be apparent that there will be no distortion due to a multiple valued attenuation factor.

There is a possibility that g-w. telephone equipment of such a nature will be designed that the ordinary microphone with its inherent defects will be replaced by a device which will give rise to

much less distortion. It is also possible to improve the common telephone receiver in regard to faithfulness of reproduction. If, and when, these improvements are brought about, we will have in g-w. telephony a means of communication whereby practically perfect transmission of the voice may be had. But even under existing limitations the faithfulness of voice production in g-w. transmission, particularly when connection is not made to local land lines, is one of the distinguishing characteristics of this method of communication.

Another important aspect of communication is secrecy. When used as a direct private line of telephonic communication, as in the case of leased lines between business houses in different cities or for press work, we have in this method a system of communication which affords a high degree of secrecy. Common experience indicates how little real privacy obtains when employing the ordinary telephone. While radio telephony has a distinct and very important field in communication at sea, it obviously has serious limitations when employed for strictly personal and business purposes. While there is no known means of communication which cannot be "tapped," yet from the nature of the system, direct guided-wave telephony possesses the greatest element of secrecy of any telephonic means of communication. When, however, the h.f. super-channel is used as a trunk line and connected at either or both ends with local physical telephone circuits, the element of secrecy is no greater than when employing a physical circuit for the entire distance.

Another advantage of the guided-wave system is that communication may be maintained between two points when the physical circuit which serves as a guide for the h.f. waves is out of commission for ordinary telephone service. Both wires of the physical pair may be cut, the line short circuited and at least one of the wires grounded without interrupting communication over the super-channel. This has been repeatedly demonstrated and naturally means much in emergency service of all kinds.

Another feature to be noted in connection with guided-wave telephony is the flexibility of the system. When used as a through trunk channel, a given set of equipment may, as previously indicated, be instantly shifted from one physical circuit to another.

Further, the entire terminal g-w. equipment may be quickly transported from one point on a physical system to another, thus making it possible to readily increase the traffic-carrying capacity of the lines between points where a temporary congestion exists, due to seasonal or other causes.

An added element of flexibility arises from the fact that various sections of physical circuits may be tied together to establish a through super-channel for trunk operation. For instance, several physical circuits may radiate from an intermediate point. Two physical circuits centering at this point may, by suitable means, be connected for the purpose of setting up a through g-w. channel, and at the same time the two physical lines may be connected to any of the other lines centering at the point in question. In other words, the tying together of the lines for g-w. working in no way limits the flexibility of the physical lines for regular telephonic operation.

An important possible application of telephony by guided waves is that of train dispatching. Reference has already been made to the fact that energy is radiated from a physical line which serves as a guide for h.f. carrier currents. Though the amount of energy thus radiated is not great, it has been shown by practical tests that it is sufficient to make possible the establishment of telephonic communication between a moving train and the fixed stations connected to one of the physical circuits paralleling the track.

This is accomplished by installing on the train a radio-telephone equipment connected to a suitable antenna system placed at the top of a car or cars. When the two systems are properly adjusted there will be a mutual interchange of energy between the train's antenna and the physical telegraph or telephone circuit which is conveying the h.f. carrier current from a fixed station. The train equipment may be located in the baggage car with leads extending to the engine cab. The engineer could be equipped with a standard anti-noise transmitter and a receiver helmet similar to that used for radio telephony on aeroplanes. So equipped, the engineer of a train could be in continuous and reliable communication with the train dispatcher. The utility of such a system in train dispatching is obvious.

Another possible application of a similar nature to the above would be the dispatching of electric railway traffic by this type of telephony. Small low power guided-wave sets could be installed on interurban cars and the trolley wire utilized for the purpose of guiding the carrier waves to and from central fixed points. The power supply used for operating the cars is usually of such a nature that it could also be directly utilized for operating the telephone apparatus. The conductor would thus be enabled to speak directly from the car to the operating official at the central office. The necessity for installing and maintaining an independent telephone circuit for dispatching purposes would thus be obviated.

Thus, there are several important special fields for the practical application of this comparatively new means of communication.

It is, however, as private leased lines and for long trunk circuits that guided-wave telephony will probably find its greatest field of usefulness. As already indicated, ordinary local subscribers' telephones may be connected through the usual central switchboard to the high frequency apparatus, the switching being accomplished in substantially the same manner as when connecting to any physical toll circuit. In this manner, the guided-wave system is being commercially used to give additional channels for the handling of "long-haul" traffic.

Although independent guided-wave terminal equipment must be installed for each super-channel that is established, yet the initial and maintenance cost of additional physical circuits is substantially greater than the corresponding cost for the high frequency installation. In general, the financial saving increases as the length of the line increases.

In this discussion we have confined ourselves to guided-wave telephony. There is, of course, a corresponding field in connection with telegraphy. Multiplex telegraphy by means of guided waves is already a commercial fact. We hope in a subsequent paper to deal with the telegraphic aspects of the case.

In conclusion, it may be said that we have in guided-wave multiplex telephony and telegraphy a distinct branch of communication engineering—a new art—which is to command the ability of the most able minds in both pure and applied science. And who shall say whither it will lead?

Analysis of Samples of Ancient Armor. (*Chem. and Met. Eng.*, November 17, 1920, p. 975.)—The analysis and microscopical examination of about one dozen samples of ancient armor from the Metropolitan Museum of Arts, New York, have been practically completed by the Bureau of Standards. The analysis indicates that all the samples were made from very pure wrought iron converted into steel by the old cementation process, as would be expected.

The carbon determination was made on the entire cross-section, as the material of all the pieces was too thin and corroded to obtain samples from different layers.

The microstructure indicates that the process used in the production of the original iron was very similar to our wrought-iron process. The metal was then carbonized, probably by a supplementary process, hammered into sheets, differing in hardness—*i.e.*, in the amount of carburization—and these sheets were welded together.

The whole was then hammered into shape and quenched, thus producing the final hardening effect.

Dyeing of Artificial Silk.—A research on the dyeing of artificial silk, manufactured by the viscose process, has been made by LEONARD PHILIP WILSON and MARJORIE IMISON (*Journal of the Society of Chemical Industry*, 1920, xxxix, Transactions, 322–324). All direct cotton colors cannot be used with artificial silk, since many of these dyes are extremely sensitive to the small differences of dyeing affinity which characterize such silk. Evenness in dyeing at the usual temperature (50° C.) varies with the molecular weight of the dye, and apparently is not influenced by the nature and arrangement of the groups of atoms which constitute the molecule of the dye. Thus Rosophenine 10 B (molecular weight 600) and Indoine Blue (molecular weight approximately 521) dye evenly, while Dianol Fast Pink B. K. (molecular weight 944) and Dianol Sky Blue (molecular weight 992) dye very unevenly, and Diamine Green B (molecular weight 812) dyes fairly unevenly. Hence a fabric of artificial silk may show variations in shade if dyed with colors of high molecular weight, and will be of practically uniform shade if dyed with colors of low molecular weight. If the temperature of the dye bath be elevated, say to 75° C., and the silk then be introduced, more even dyeing is obtained. A mixture of even and uneven colors in a dye bath almost always yields worse results than are obtained with uneven dyes alone. Deficiencies in the direct colors may, at times, be overcome by use of sulphur dyes. Basic colors produce extremely bright shades and even dyeing on artificial silk; if a mordant be used, the most even results are obtained by dyeing in a neutral bath, then fixing in tannin and tartar emetic.

J. S. H.

A Photographic Method of Finding the Instantaneous Velocity of Spark Waves. A. L. FOLEY. (*Phys. Rev.*, November, 1920.)—On the assumption that the displacements concerned in a sound wave are infinitely small, Newton derived an equation for the velocity of sound which gave the same velocity for all sounds. From the experiments of Regnault it has been known that loud sounds travel faster than faint ones. This difference has been the subject of much consideration, both theoretical and experimental.

At about the middle of a long, narrow box two terminals were placed between which passed the spark producing the sound. Its axis was parallel to the length of the box. At one end of the box was rotated a steel disk on whose edge were notches irregularly spaced and of different depth to furnish individuality for identification. The sound spark projected the shadow of the notches on a photographic plate placed close to the disk and with its plane parallel to that of the latter. A little after the sound spark had jumped a second spark, the illuminating spark, was produced at the end of the box distant from the steel disk. During the interval between the two sparks the sound wave from the first spreads out. Its shadow in the light of the second spark is projected on the plate and is photographed. The disk, too, has been rotating and the shadow of its notches are photographed again. The two impressions due to the same notch will not coincide, not only because the disk has rotated, but also because the source of the light in the two projections is different. From the dimensions of the apparatus, the speed of the disk and the location of the two photographs of the same notch, it is possible to calculate the interval in seconds between the production of the two sparks. From the radius of the shadow of the sound spark the distance the sound travelled in the interval between the two sparks can be found. From these data the velocity of the wave is derived. The illuminating spark could be made to appear at varying intervals after the sound spark, and thus the sound was given different lengths of time in which to expand before it was photographed.

When the wave had proceded 3.2 mm. from its origin the velocity was found to be 678.6 m. per second—almost twice that of normal sound waves. This became rapidly less as the wave spread out, becoming nearly normal at 20 mm. from the source. The velocity of the wave increases when the intensity is increased, whether this be accomplished by changing the spark or by merely examining the wave closer to its source.

The comparison of the photographs of two parts of the same wave, one of which travelled in free air while the other passed through a tube, showed that the latter outran the former and, in fact, had a velocity about 22 per cent. greater.

The methods employed by Professor Foley are elegant and make an appeal to the esthetic as well as to the scientific judgment.

G. F. S.

THE MODERN CARGO VESSEL.*

BY

WILLIAM GATEWOOD.

Newport News Shipbuilding and Dry Dock Company, Newport News, Va.

THE cargo vessel has proved of inestimable value to mankind from the days of Noah, when the "Ark," the first "cattle" ship of which we have a record, saved the people of Western Asia from starvation and from death from exposure, to the present century, when the modern cargo vessel has saved the people of Western Europe from as dreadful a fate. Civilization is made possible by commerce, and as commerce cannot thrive without suitable means of carriage, the humble cargo vessel is the handmaid of progress.

The cargo vessel, like so many other live institutions, has been an evolution, and the type of vessel has adapted itself to the needs of its day and generation. The primitive type was a raft, without means of locomotion, and with a pole for steering. This was probably succeeded by the canoe, with pole for pushing as well as for steering, and later with paddles replacing the pole. As the necessity arose for larger vessels, the oar replaced the paddle. Man does not care to burden his life with any labor which can be avoided, and some lazy man, as like as not, discovered that the wind would relieve him of exertion if he would rig up a sail. So sailboats became common, and the rowing galleys were manned only by convicts condemned to hard labor for life.

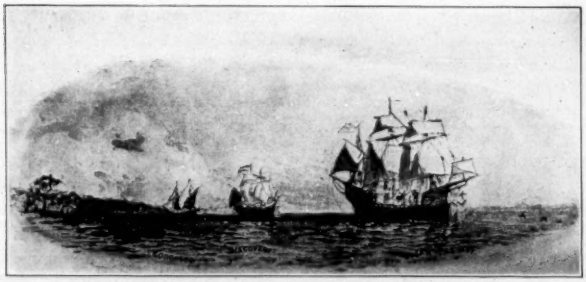
In order to appreciate the real value of the modern cargo vessel, and its adaptability to the needs of the twentieth century, it will be advisable to note the status of self-propelled vessels at various epochs. It will not be necessary to go further back than the discovery of America, as that marks the real beginning of ocean transportation. The flagship of Columbus is stated to have been a vessel about 100 feet long and its gross tonnage, according to present measurement, was about 250 tons. The records indicate an average speed of only four knots on the voyage to this side of the Atlantic, although the wind was favorable most of the time.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, January 13, 1921.

The size of vessels increased considerably during the century immediately following the discovery of America, and the Spanish, in particular, carried on considerable trade between the Philippines and Panama and thence to Spain. The English vessel of this date was still quite small, as the largest of the vessels which landed the first colonists in Virginia in 1607 was only about 80 ft. long.

The advent of the marine steam engine in 1807, or thereabouts, marks one advance without which the modern cargo vessel could not have been developed. For many years steam power was applied through paddle wheels, and seagoing wooden paddle steamers were in use for transatlantic travel from 1819, when the

FIG. 1.



Atlantic liners, seventeenth century.

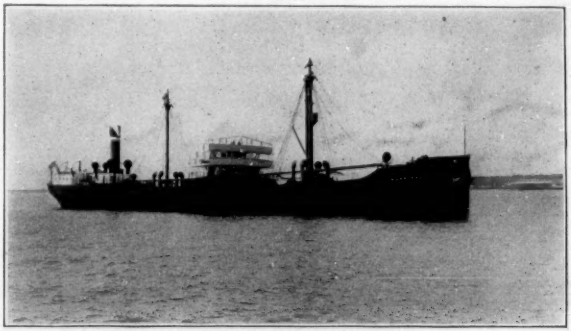
American steamship *Savannah* made her maiden voyage, until after the Civil War.

Two other essential developments were made during the nineteenth century. The screw propeller was perfected so as to be commercial, the first use on a merchant vessel of which I have been able to find a record having been in 1838 on the *Robert F. Stockton*. In 1841 only three English merchant vessels had been fitted with screw propellers. This type of propeller removed the primary disadvantage of steam propulsion, and its later development definitely relegated the sailing vessel to a minor position in the world's commerce.

The application of iron and steel to ship construction was the other development which has made the modern cargo vessel possible. The first iron steamboat was the *Aaron Manby*, built in

1820, for service between London and Paris. The first iron vessel to cross the Atlantic is stated to have been the first screw steamer previously mentioned, the *Robert F. Stockton.* Many of the early iron vessels were small, but the possibilities of iron in ship construction were foreshadowed in the *Great Eastern,* 680 feet long, which was begun in 1854 and completed in 1859. No other vessel of that date exceeded 400 feet in length, so that a large step forward was made at that time in the size of vessels. While the *Great Eastern* accomplished a useful work, particularly in laying the first submarine cable, it was too large for the commerce of its

FIG. 2.



For coal or bulk freight. Gross tonnage, 4300.

day, and could not be considered a commercial success. I find a record in a notebook of my father, who was then living in Norfolk, Va., under date of August 4, 1860, which reads: "To see the *Great Eastern*—$2.00."

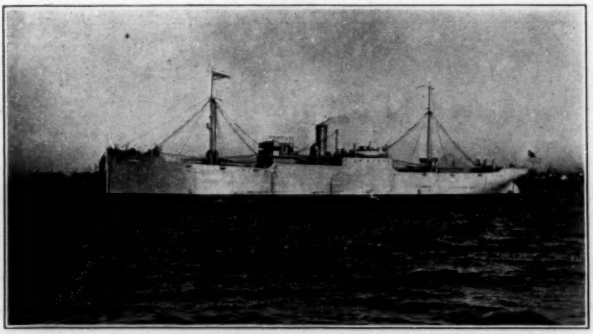
Mild steel was introduced in about 1876, and the modern cargo vessel is possible only on account of the development of the steel industry, in which the State of Pennsylvania has played no mean part.

The modern cargo vessel is built of mild steel, is propelled by a screw propeller operated generally by steam machinery, is steered with a rudder operated by steam and controlled from the bridge, is navigated by magnetic compass, has its location determined by chronometer and sextant, and has its cargo handled by block and

tackle from booms on masts or derrick posts by means of steam winches. The size, arrangement, speed and fuel are specialized to suit the exact requirements of the trade, and few trades call for exactly the same design.

The cargo vessel of the future may be built of high tensile or special steel, but there are no indications at present that mild steel will be superseded in the near future, except on the largest vessels. It may have some other kind of propulsion than by a screw propeller, but there are no indications of any more efficient

FIG. 3.

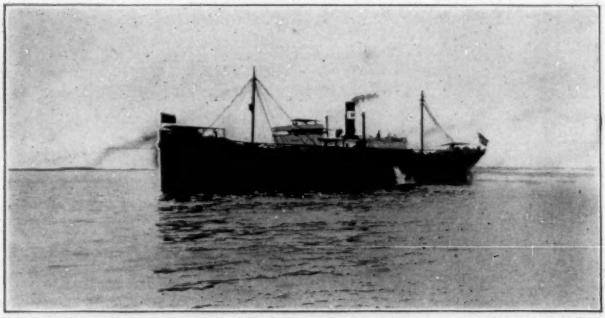


A cargo vessel of 7500 tons deadweight.

method, although some improvements may be made in the type of screw. The reciprocating steam engine is being superseded by the geared turbine, and the turbine is being used also in conjunction with electric generator and motor, instead of gears. The water tube boiler for generating steam is now becoming almost as well known as the cylindrical boiler, and the majority of new vessels use oil as fuel instead of coal. The internal combustion Diesel engine is being developed and used, and it is possible that this will be the prime mover of the future on account of its economy, unless oil becomes too expensive to be used at all. Electric motors are well suited for operating any type of steering gear, including hydraulic, and when steam is not used for propulsion, electric auxiliaries are the natural arrangement. The gyro-compass may

replace the magnetic compass, as the gyro-compass is now used on Atlantic liners and in the navy. The variation of the magnetic compass, first discovered by Columbus, is still a source of confusion, and the deviation of the compass due to the ship's magnetism is a continual cause of anxiety to the navigators. No substitutes for the chronometer and sextant are being experimented with, so far as I know, but the "wireless" is already being used to give the location near the coast in a fog, and to check the time. Electric winches are common on naval vessels

FIG. 4.



A cargo vessel of 9600 tons deadweight.

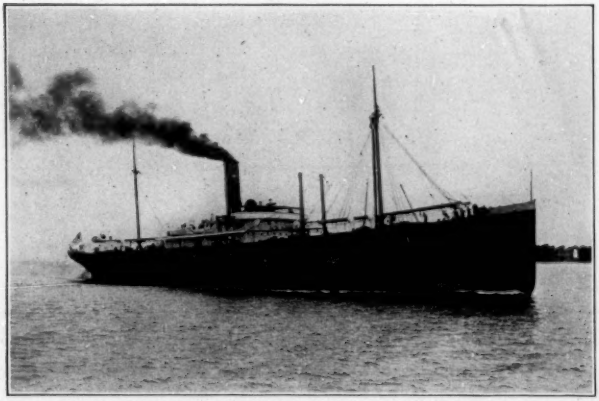
and are used also when internal combustion engines constitute the propelling mechanism.

Reinforced concrete is being used in the construction of cargo vessels to a limited extent. The aggregate used weighs much less than that used in land construction, so that the concrete vessel is not so very much heavier than the steel vessel. Concrete, however, is liable to develop cracks under tensile stress, and the sides seem to be susceptible to damage in docking. It does not seem likely to be much used for ship construction in the future. In a well-designed steel vessel of large size, almost all of the steel is required to withstand tensile stress, and so no reduction in the amount of steel used for reinforcement could be made, as the concrete is of value only in compression. The weight of the concrete must be almost entirely in excess, therefore; and the reduction

in cost of construction, if any, can hardly be great enough to offset the loss in deadweight.

The size of a cargo vessel is made to suit the length of voyage and the amount of cargo available. There is no economy in having a large vessel in a given trade unless the vessel can be fully loaded on most of her trips. The commercial life of a vessel may be taken as twenty years, and a depreciation of at least 5 per cent. per annum on the investment should be allowed as a part of the cost of operation. Not less than 5 per cent. interest on the invest-

FIG. 5.



A shelter deck liner, 14 knots speed.

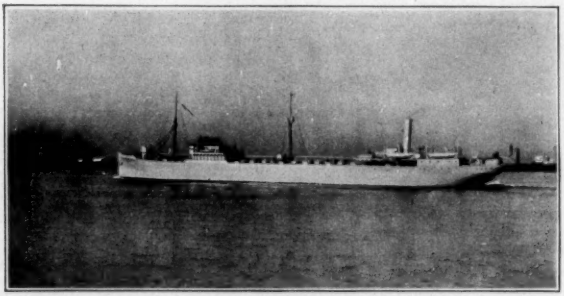
ment should be gained in addition, and repairs will amount to an average of not less than say 2 per cent. of the first cost, so that not less than 12 per cent. of the first cost must be carried each year in addition to the cost of operation. The first cost, therefore, is of prime importance in determining the particulars of a vessel. Other things being equal, the cost increases with the size, and therefore the vessel should not be larger than the amount of cargo justifies.

The economy in operation resulting from increase in size, however, is very great. It takes very few more in the crew to man a vessel of 10,000 tons than to man a vessel of 5000 tons, as

the same number of licensed officers are required on each vessel and only about six additional men are needed in the crew. The horsepower required for the same speed is increased in the larger vessel by only about 50 per cent., and the machinery may be made somewhat more economical so that the fuel consumption will be increased by less than 50 per cent. If the operating costs of crew, fuel and supplies amount in the course of a year to 30 per cent. of the first cost in the case of the smaller vessel, they would amount to only about 24 per cent. in the case of the larger vessel.

The larger vessel would carry about two and a quarter times as

FIG. 6.



Tanker, shelter deck type.

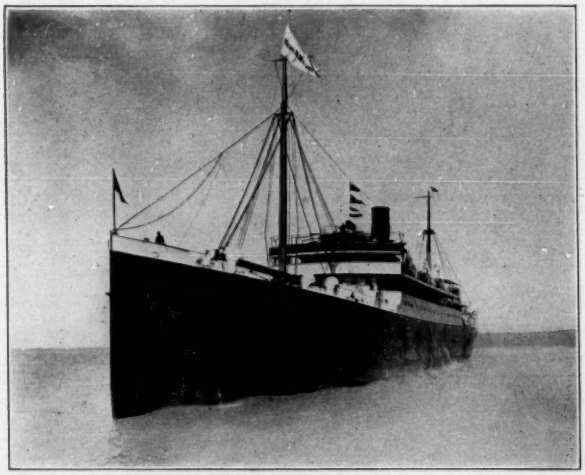
much cargo in the course of a year, as the machinery and fuel would occupy proportionately less space and weigh proportionately less, and the number of voyages need not be less, as the slight increase in the time in port, if any at all, would be counterbalanced by the less interference with regularity of speed on account of bad weather.

The first cost of the larger vessel would be considerably less than double that of the smaller vessel, on account of the fact that the weight and cost of the hull and fittings is not twice as great and the cost of the machinery would be only about one and a half times as much. The first cost may be taken as about 1.8 times as great.

The advantage of doubling the size of a vessel, then, may be summarized as follows:

The carrying capacity of the larger vessel will be about 2¼ times as great.
The operating cost of the larger vessel will be about 36 per cent. of its first cost when the operating cost of the smaller vessel is 42 per cent. of its first cost.
The first cost of the larger vessel will be about 1.8 times the first cost of the smaller vessel.
The comparative cost of operation of the larger vessel per ton of cargo will be only about three-quarters as much as the similar cost for the smaller vessel.

FIG. 7.

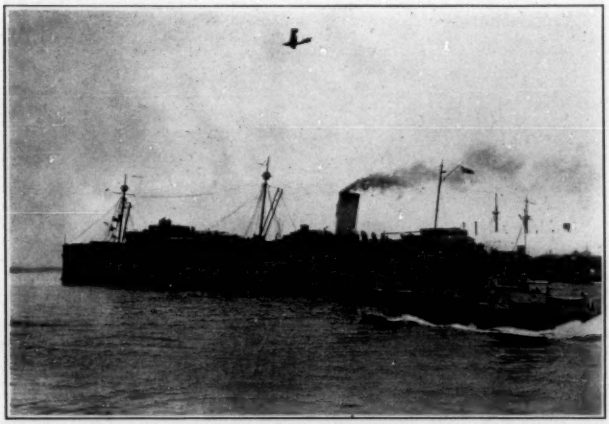


For passengers and package freight. Troops during the war.

The natural thought would be that by increasing the speed of a vessel quite an advantage would be gained. Such is seldom the case, however. If a vessel, for instance, has a speed of 9 knots and spends two weeks at sea to one in port, the first cost of a vessel to carry the same weight of cargo each trip would be nearly double for an increase in speed of 50 per cent., and the cost of operation would be at least double, while the faster vessel would carry only 30 per cent. more cargo in the course of a year. It is this economic fact which keeps the average speed of cargo vessels so nearly the

same as it was twenty years ago. The tendency in this country, however, is to build for a speed of between 10 and 12 knots, and few vessels are being built of less speed than 10 knots. The effect of bad weather is much greater on the slower speed vessels, and the increased length of time the cargo is in transit operates to reduce the freight rates. It is generally conceded that only vessels for carrying passengers and express freight should be designed for speeds in excess of 16 knots, and quite a number of passenger

FIG. 8.



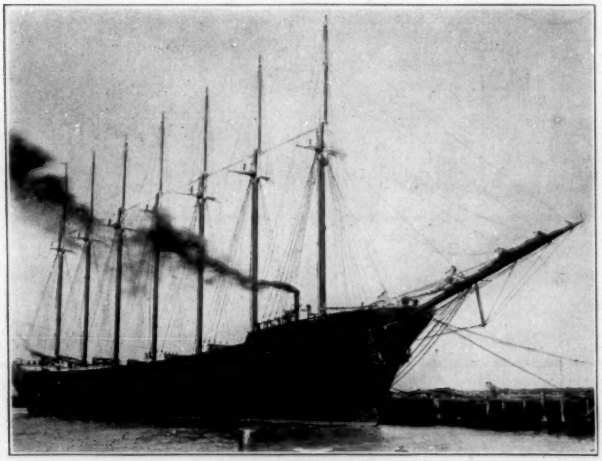
In pace decus, in bello praesidium.

vessels are running at a speed of about 14 knots. The larger the vessel the less the economic disadvantage in the higher speed, as the power required for the same speed does not increase directly as the size of the vessel but only as about the two-thirds power of the displacement, and a somewhat higher speed can be obtained without using as great a proportion of the displacement for machinery and fuel.

The underwater form of a vessel may be made quite bluff if a low speed is deemed sufficient, but the lines must be made finer as a higher speed is sought. The block coefficient is the term used to denote the proportion which the volume of the vessel

under water bears to the circumscribed parallelopiped. For a speed of 10 knots the block coefficient is about 80 per cent. in a vessel 400 ft. long, and may be increased to 82 per cent. in longer vessels, while it would be reduced to 78 per cent. in a vessel 350 ft. long. It ranges between 78 and 82 per cent. in the ordinary cargo vessels. As the speed increases, the block coefficient is reduced, and in some recent freight and passenger vessels 518 feet long and

FIG. 9.



Seven-masted steel schooner.

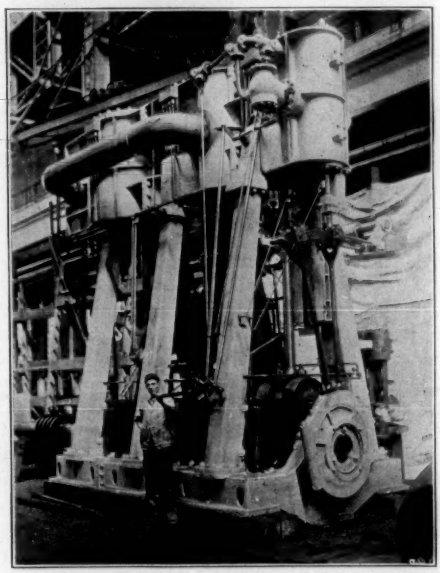
designed for a speed of 16–17 knots, it was made as small as 65 per cent.

The high cost of construction of the hull, and the broken stowage, however, do not recommend such a fine block even though a higher speed is obtained for the same power. Bad weather reduces appreciably the speed of a very fine vessel, causing heavy pitching, so that a vessel should be neither too bluff nor too fine. The present tendency on cargo vessels is toward a fining of the bluff bows which were so common earlier in the century, and also toward fining the stern, not only to preserve the trim, but also

to give a better flow of water to the propeller and to gain in efficiency of propulsion thereby.

The above water form of hull of modern cargo vessels provides usually a flaring bow in order to prevent the waves from breaking over the deck, a smooth sheer line with about twice the rise forward as aft, with erections to suit the needs of the service. In most

FIG. 10.



Triple expansion engine, 1200 I. H.-P.

of the fabricated vessels there is no sheer at all, but such vessels are not as good sea boats, and under the present rules for determining freeboard they cannot load as deeply. Many vessels have been built in this country with a straight sheer for the half length or more amidships and with a quick sheer forward and the usual amount of sheer aft. This practice simplifies the construction, increases the strength somewhat, and does not offend the average

eye. It will probably come into more general use, especially when the rules for determining freeboard are made rational instead of empirical.

Vessels with forecastle, bridge and poop are still the most common, although the shelter deck type is coming more into favor. The latter provides more cubic space for the same weight of cargo, and is better adapted for general cargo on that account.

The submarine is not likely to be a competitor with surface vessels in the carrying of cargo, as all the troubles of surface vessels are magnified greatly when the complications of running submerged are added.

Cargo vessels may be divided into two general classes—liners and tramps. The former are like business men who travel between home and office with an occasional stop off at the club for lunch. The name of the latter is a misnomer as they do not correspond to tramps at all, but more nearly to the harvest hands who work wherever they can find work to do.

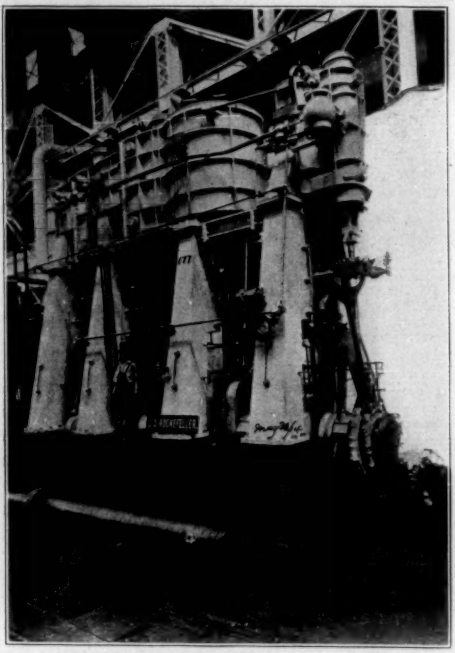
If a vessel is not always sure of a return cargo, and has no means provided for a large amount of water ballast, the machinery is usually placed amidships. This is the common type. In oil tankers, colliers, and a few liners, including some vessels carrying passengers, the machinery is located aft, and this type of vessel is becoming quite numerous. The midship portion of the vessel is the best for carrying cargo, while the machinery fits very nicely in the stern, and the troublesome shaft alleys are avoided.

The type of steam engine installed on most cargo vessels is the inverted vertical three-cylinder triple-expansion reciprocating engine. This type has been in use for about forty years, the first successful one having been installed in 1881 in the *Aberdeen*. It has been improved in details, and the ratio of expansion has been increased as the boiler pressure was raised, but it is essentially the same machine, and engineers have become so accustomed to it that a breakdown in service is almost unknown. A number of four-cylinder triples are in service, and the four-cylinder quadruple engine is quite common in liners, and very economical.

The geared turbine was introduced in cargo vessels in 1910 by Sir Charles Parsons on the *Vespasian*, as the only method of using steam turbines on slow speed vessels with any economy. The modern gears are not of the same type as were used sixty years ago in the *Great Eastern*, for instance, but are of steel cut

with the minutest accuracy. A high speed of revolution is necessary in order that a steam turbine shall function with economy in the use of steam, while a slow speed of revolution is necessary in order that the propeller shall be efficient. A gear ratio of

FIG. 11.



Quadruple expansion engine of 2800 I. H.-P.

15 to 1 is about the average for a single reduction, while a ratio of between 30 and 40 to 1 is used with double reduction gears. Both the Curtis and Parsons type of turbines are in common use, but neither have displaced the reciprocating engine as yet. So many are now in use that the reliability of both the turbines and gears will be determined shortly, and as they weigh less, take less

room and have possibilities of economy greater than the reciprocating engine, they seem sure of an extended use in the future.

Electric propulsion was introduced on the Navy collier *Jupiter* in 1913 by the General Electric Company, and has recently been fitted on merchant vessels. In this system of propulsion an electric generator is driven by a high-speed turbine, and the propeller is operated at a suitable speed by a motor. The steam consumption is very moderate, and some eminent marine engineers in this country consider that the electric drive is one of the coming forms of propulsion for cargo and passenger vessels. It is slightly heavier than the reciprocating engine and much heavier than the geared drive, and probably will prove more expensive to build, so that its future use will depend on how well it can overcome these handicaps in the course of its development.

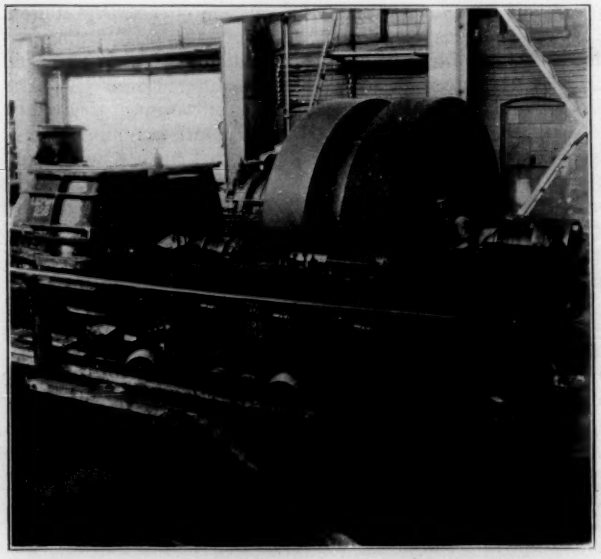
The internal combustion oil engine for marine use was introduced in Italy in 1910. It has been developed up to units of slightly over 2000 horsepower, and its consumption of fuel oil is reported to be only half as much as in the best form of steam machinery. In its present state of development, it is considerably heavier than steam machinery of the same power. The earlier installations have not always proved reliable, but as experience has been gained in its design, construction and operation it has given greater satisfaction in service. At present, its first cost is considerably in excess of steam machinery, and the power of a single unit is limited, so that it offers no immediate advantage financially except on long voyages, on which the saving in the fuel supply needed will enable a heavier cargo to be carried. A recent American installation is that on the *Cubore*, which came out in the summer of 1920.

The use of steam machinery for marine purposes was handicapped until the cylindrical multitubular boiler, commonly called the "Scotch" boiler, was developed in about 1862. As the steel mills became able to roll larger and thicker sheets, this type of boiler increased in size and ability to carry heavier steam pressure, so that one single-ended four-furnace boiler 17 ft. in diameter can now be built to generate steam at 200 lbs. per square inch, sufficient for an indicated horsepower of 1200 or more, although three-furnace boilers for a working pressure of 160 to 180 lbs. are the common size. This type of boiler can be used to burn either coal or oil, and like the reciprocating engine, it is so well known

that a breakdown in service is rare, although repairs on account of carelessness are not as infrequent as they should be.

The water-tube boiler was introduced in the merchant service about twenty-five years ago, and has been used quite extensively recently, especially in connection with oil as fuel. It is considerably lighter than the Scotch boiler, but, on account of the small amount

FIG. 12.



Geared turbine, 6000 S. H.-P.

of water contained, it requires more care in operation. The Scotch boiler has nothing to recommend it theoretically, but its reliability keeps it in use, and like the reciprocating engine it is likely to be installed in cargo vessels for many years yet.

The fuel used in cargo vessels until quite recently was bituminous coal. Anthracite coal was discarded after a few years of use, as it was found to be more difficult to adapt to the varied requirements

of service. Many cargo vessels do not have artificial draft, but quite a number of coal burners are fitted with heated forced draft, introduced by James Howden in 1884. Since the advent of fuel oil, its use on board ship has been extended so that very few vessels of the present day are designed for coal burning, although the greater number of the vessels afloat still burn coal. The tramp and the liner are both dependent on fueling stations. Very few vessels carry enough fuel for a round trip, and some of the routes are so long that fuel must be taken on at an intermediate station. The United States has about twenty-one commercial fueling stations at which oil can be obtained, in addition to its home ports. England has numerous coaling stations scattered over the world, but fuel oil is not obtainable except at a comparatively few ports, so that tramp steamers cannot use oil with satisfaction. At first, steam was used to atomize the oil, but that method was found unsatisfactory on account of the waste of fresh water involved, and at present the oil is heated to vaporizing temperature and sprayed mechanically. Heated forced draft is used to burn the sprayed oil, in most cases, and very satisfactory economy is obtained.

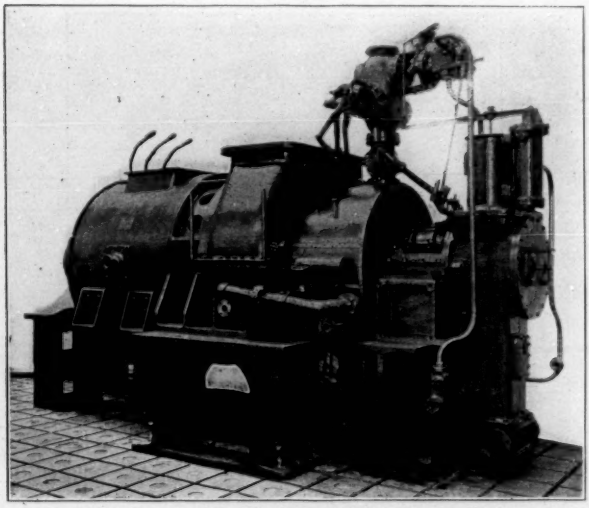
Ships are built to stay at sea in stormy weather, and their structure must be strong enough to withstand wind and wave. In the days of the wooden ship, the effect of storms was shown first in the working of the seams, and pumping had to be resorted to regularly to keep down the leaks. In steel ships, the strength of the bottom of the vessel is usually greater than that of the deck, and the riveted seams do not leak so easily, so that except in old vessels a defect of strength was indicated by the posting of the vessel as missing. The stresses in a vessel are greatly increased if the vessel is overloaded, but the effect of overloading is not felt except in a storm. It was some time before this fact was properly appreciated, and a limit to the loading was found to be necessary.

In Great Britain, Mr. Samuel Plimsoll took the matter up in 1875, and an Act of Parliament was passed requiring a mark to be located amidships on each side deeper than which a foreign-going vessel should not be loaded. This mark is known as the "Plimsoll" mark. Its location is determined for British vessels since 1890 by certain rules known as Freeboard Tables based on retaining a certain percentage of buoyancy at the load draft, and

assuming that the strength of the vessel was that obtained by using the scantlings required for the vessel by Lloyd's Register of Shipping and set forth in Lloyd's Rules.

In the United States, there is no legal enactment to prevent overloading, although a Committee has been appointed by the Secretary of Commerce to formulate recommendations. A British committee has recently proposed a modification of their

FIG. 13.



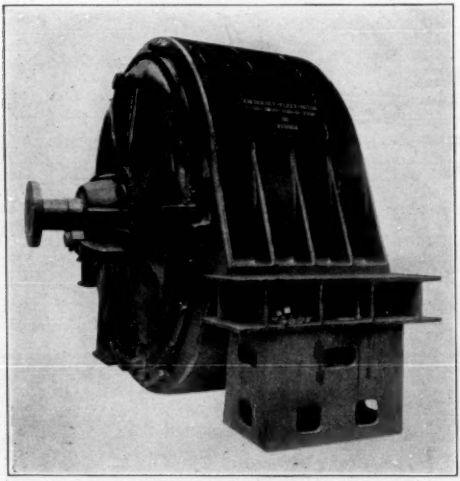
Marine turbine generator, 3000 I.H.-P.

freeboard tables basing the loading on an absolute criterion of strength, so that the stronger a vessel the deeper she will be allowed to load. With proper precautions as regards the tightness of hatches and the safety of movement of the crew, this would seem logical. It is hoped that our Government will afford a similar measure of protection to the humble cargo vessel. In the matter of loading, the stresses increase more rapidly as the draft increases, and even a foot of overloading is likely to strain the

structure in a storm, and if persisted in to cause the loss of the vessel.

The hull of a vessel is essentially a hollow girder. The shell is stiffened by frames, and is subdivided by diaphragms called bulkheads, if vertical, and called inner bottom or decks, if horizontal. The weather deck of steel and iron cargo vessels for a number of years was made of wood, later of iron or steel sheathed with wood,

FIG. 14.



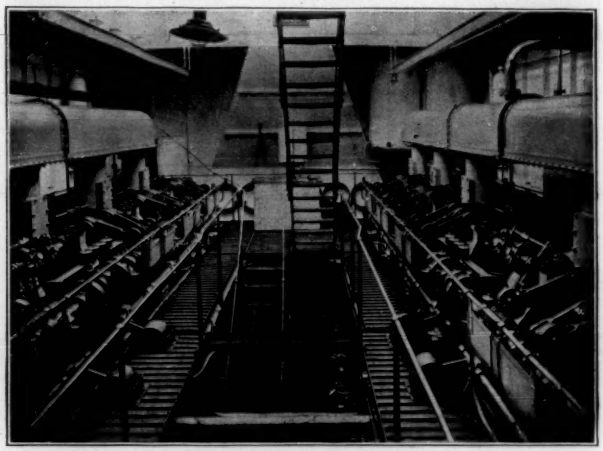
Induction motor, 3000 H.-P.

but in general wood decks have been discarded except over the quarters for the crew and passengers. In the early days of iron ships, only bars and plates were rolled, but the advantage of rolled shapes was so apparent that angle and other sections were soon obtainable in a great variety of sizes. In the ordinary cargo vessel about two-thirds of the steel is plates and one-third shapes.

Following the method of framing adopted in wooden vessels, the frames were fitted transverse to the length. This type of framing was the only type which could be used in composite

vessels; that is, vessels with metal frames and wood planking. The classification societies prepared rules for the scantlings with transverse framing, and as transverse frames are easily fabricated and erected, this type of framing became the sole type used for many years, and is now used on the majority of cargo vessels, with the exception of tankers. In the middle of the nineteenth century, John Scott Russell developed the longitudinal system of framing, as exemplified in the *Annette*, the *Great Eastern*, and

FIG. 15.



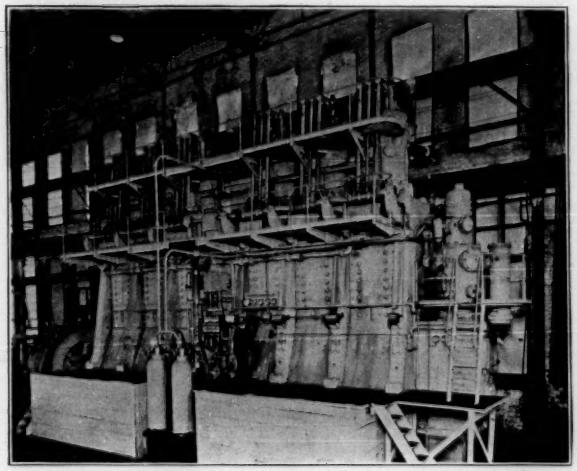
A Dutch installation of Diesel engines.

a number of others. In this system, there are a number of widely spaced rigid transverse members which support longitudinal frames by which the shell plating is stiffened. This method of framing went out of use, because channel and bulb angle sections were not rolled at that time, and the cost of fabrication and erection of the plate and angle sections was too great. The advent of the bulk oil carrier, the tanker, showed the necessity for some type of framing better suited than the transverse, and the longitudinal system was re-introduced by Mr. J. W. Isherwood in 1908, using rolled sections for the longitudinal frames and making

the transverse members much deeper than the longitudinals so that the latter could fit in slots cut in the edge of the transverses. This type of framing has proved very satisfactory on tankers, greater strength being obtained with less weight of material. It is used with advantage on other types of vessels also, but transverse framing is still the more popular for ordinary freighters.

It is very difficult to calculate the stresses to which the various

FIG. 16.

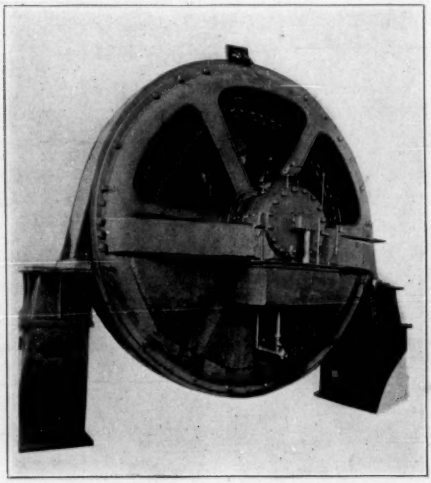


A Diesel engine built in America.

parts of a ship are subject, so that it was early found necessary to prepare tables and rules giving the scantlings to be used in the construction of the hull and machinery of vessels of ordinary size. These rules were mostly empirical, and a damage on one vessel was often the occasion for penalizing all vessels thereafter built. These rules were issued by classification societies, and if a vessel were built according to the rules it was eligible for classification, and upon payment of a fee it was assigned a class. The classification societies issue register books listing the general particulars of all vessels, including their class or rating, and this

rating is accepted by the marine underwriters in fixing the premium for insurance on the vessel and its cargo. To be efficient, a classification society must have surveyors at all the principal ports, as well as at the building yards, so that proper repairs may be required in case of breakdown. Inspection at frequent intervals is required in any case, as deterioration and wear are inevitable, and many so-called accidents are avoided by remedying

FIG. 17.



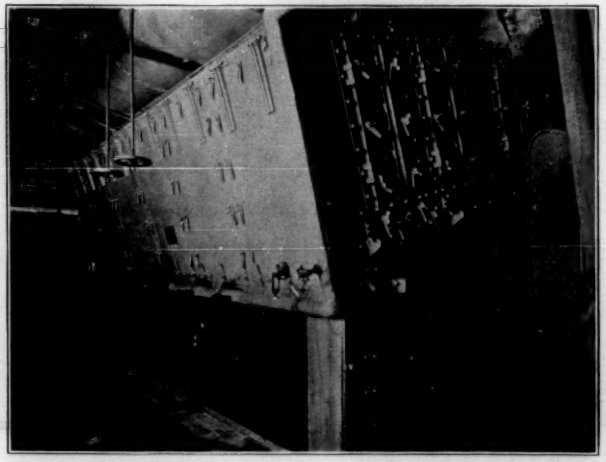
Synchronous motor, 3000 H.-P.

the defects disclosed by these periodical surveys. The dominant society is Lloyd's Register of Shipping, an English society which is godfather to more cargo vessels of all nationalities than any other. In the United States, the American Bureau of Shipping has been recently strengthened, so that it is no longer necessary to rely on a foreign institution for the classification and survey of vessels under the American flag.

The question of insurance and underwriting is of prime importance, as very few shippers are willing to trust their goods in

the cradle of the deep, no matter how staunch the vessel may be in which they are rocked. Even the United States Government requires insurance on everything belonging to it that is not carried on a naval vessel—a procedure which is not warranted by the underlying basis for insurance, as it can well afford to carry its own insurance. Steps are being taken at the present time to extend American underwriting, so that we may be independent of

FIG. 18.



Oil-burning water-tube boiler.

foreign nations in that respect also. This is particularly fitting, as a ship of a country carries its flag and represents its nationality.

A cargo vessel considered as a unit may be likened to a beast of burden—seldom good-looking and usually devoid of dignity. It needs a certain amount of care from those in authority, however. It should not be overloaded, else its back will break—and vessel, cargo and crew are likely to be lost. It must not be driven too hard else the boiler will explode, or the shafting break, or the steering gear become deranged—and the sea is not safe for a vessel which is not under control. It should have careful officers,

Congreſs of the United States:

AT THE SECOND SESSION,

Begun and held at the City of New-York on Monday the fourth of January, one thouſand ſeven hundred and ninety.

An ACT *impoſing Duties on the Tonnage of Ships or Veſſels.*

BE *it enacted by the* SENATE *and* HOUSE *of* REPRESENTATIVES *of the United States of America in Congreſs aſſembled*, That upon all ſhips or veſſels, which after the firſt day of September next, ſhall be entered in the United States from any foreign port or place, there ſhall be paid the ſeveral and reſpective duties following, that is to ſay: on ſhips or veſſels of the United States, at the rate of ſix cents per ton: on ſhips or veſſels built within the United States after the twentieth day of July laſt, but belonging wholly, or in part to ſubjects of foreign powers, at the rate of thirty cents per ton: on other ſhips or veſſels at the rate of fifty cents per ton.

And be it further enacted, That the aforeſaid duty of ſix cents per ton, ſhall be alſo paid upon every ſhip or veſſel of the United States, which after the ſaid firſt day of September next, ſhall be entered in one ſtate from a diſtrict in another ſtate, other than an adjoining ſtate on the ſea coaſt, or on a navigable river, having on board goods, wares and merchandize taken in one ſtate, to be delivered in another ſtate: *Provided*, That it ſhall not be paid on any ſhip or veſſel having a licenſe to trade between the different diſtricts of the United States, or to carry on the bank or whale fiſheries whilſt employed therein more than once a year.

And be it further enacted, That upon every ſhip or veſſel not of the United States, which after the ſaid firſt day of September next, ſhall be entered in one diſtrict from another diſtrict, having on board goods, wares and merchandize taken in, in one diſtrict, to be delivered in another diſtrict, there ſhall be paid at the rate of fifty cents per ton.

And whereas, it is declared by the twenty-third ſection of the act, intituled, "An act for regiſtering and clearing veſſels, regulating the coaſting trade, and for other purpoſes," "That if any veſſel of the burthen of twenty tons or upwards, not having a certificate of regiſtry or enrollment, and a license, ſhall be found trading between different diſtricts, or be employed in the bank or whale fiſheries, every ſuch ſhip or veſſel ſhall be ſubject to the ſame tonnage and fees as foreign ſhips or veſſels," which, from the impracticability in ſome caſes of obtaining licenſes in due ſeaſon, and from miſapprehenſion in others, has operated to the prejudice of individuals; and it being proper that relief ſhould be granted in caſes where the ſtrict operation of new laws may have occaſioned hardſhip and inconvenience;

Be it therefore further enacted, That in all caſes in which the ſaid foreign duty ſhall have been heretofore paid on ſhips or veſſels of the United States, whether regiſtered at the time of payment or afterwards, reſtitution thereof ſhall be made, and that no ſuch foreign duty ſhall hereafter be demanded on the ſaid ſhips or veſſels.

And be it further enacted, That the act, intituled, "An act impoſing duties on tonnage," ſhall, after the ſaid firſt day of September next, be repealed, and ſhall thenceforth ceaſe to operate, except as to the collection of the duties which ſhall have accrued prior to the ſaid repeal, for which purpoſe the ſaid act ſhall continue in force.

FREDERICK AUGUSTUS MUHLENBERG,
Speaker of the Houſe of Repreſentatives.

JOHN ADAMS, *Vice-Preſident of the United States, and Preſident of the Senate.*

APPROVED, July the twentieth, 1790.

GEORGE WASHINGTON, *Preſident of the United States.*

(TRUE COPY.)

Th. Jefferſon *Secretary of State.*

Early marine legislation.

else collision, grounding or shipwreck will result, and the repair bills will eat up the profits even if the vessel and cargo are saved. The Steamboat Inspection Service is empowered by the Government to examine and license the officers of a vessel and to inspect the machinery and hull. The owner of an American vessel is allowed to load his vessel as he may consider expedient, however, and while he often gets by with a foot or two of extra draft, there are many cases of vessels never being heard from which are doubtless lost on account of overloading. The British shipowner was equally inconsiderate not so many years ago, but the load draft of British vessels is now limited by law, and the Plimsoll mark placed on each side amidships defines the draft, as previously mentioned.

Cargo vessels of a country considered as a group, together with the passenger vessels, form its Merchant Marine and should be invested with the dignity of upholding the honor of the country in the ports of the world. No country can live to itself. Japan of a century ago is the nearest example of a nation of any size attempting to be self-contained. As soon as it opened its ports to commerce, however, it began to grow and develop, until now it is one of the influential nations of the world. The United States has natural resources unsurpassed by any other country, but it is dependent on other countries for certain commodities which are not found or raised here in sufficient quantities to satisfy our wants. We import coffee from Brazil, sugar and iron ore from Cuba, nitrates from Chile, cork from Spain, oil from Mexico, and various other commodities from other countries.

It is generally recognized that this country should be as self-supporting as possible, and for many years our manufactures were encouraged by a protective tariff. But no country can excel in all kinds of manufactures, so that our imports of manufactured goods are of large volume and are likely to continue large. On the other hand, we have for export foodstuffs, cotton, coal, oil and the manufactured products in which we excel. Civilization is advanced by this interchange of commodities and prosperity is dependent on it. Some countries excel in the building or operation of ships. Such countries do most of the carrying trade of the world, and rightly so. But a country as large and powerful and influential as the United States loses a measure of its independence when it allows other nations to carry all of its foreign commerce. It is as much

an essential that it shall carry a large proportion of its commerce as that it shall manufacture the major portion of the articles it uses and raise the major portion of its foodstuffs. The more independent we are as regards raw materials and manufactures, the less need there is of a large merchant marine. But if we *must* import and export commodities, we should have a merchant marine of our own sufficient to carry what we really need. If all nations were similarly situated, the proportion of the cargo vessels of the world controlled by each would be distributed according to the amount of the commerce of each nation. Some nations, however, are not able to build or operate vessels economically and cannot afford to do their own carrying. We are not in that class. Under ordinary conditions, we cannot build and operate vessels as cheaply as some other nations. But we can afford to carry our own commerce, just as we could afford to do our own manufacturing. Our independence requires that we shall do our own carrying, and we must not fail to arrange for so doing.

How did we build up our manufactures? We did not buy other nation's manufactures just because they were cheaper than ours, but we put on a tariff that enabled us to compete with foreign goods and to build up our own industries. We must do the equivalent with ships. How? A subsidy would accomplish the purpose with us, as it has with other nations. But a subsidy is liable to abuse, and has not as yet been recognized as proper by the nation at large. Discriminating duties would accomplish the purpose in part, but would help only on vessels importing dutiable articles. Discriminatory tonnage dues would supplement the discriminating duties, and would apply to all vessels entering or leaving our ports. Tonnage dues are the nearest equivalent to the protective tariff, and could be regulated to a nicety to enable this country of ours to have such a merchant marine as our independence requires, without placing any more burden on any section of our people than the tariff did, and could be removed in whole or in part if our cargo vessels, like our manufactures, ever reach the stage of development when no protection is needed, or when all the rest of the world has the same scale of living as ourselves, if such a condition were possible.

The difference in cost of operation is so great, averaging at present probably 50 per cent. more than our competitors, that to balance the difference in freight rates required to offset the extra

cost of operation the amount of discrimination in duties, and the difference in tonnage dues, will have to be quite great for awhile at least. The money which reverts to the Treasury on account of the increased tonnage dues on foreign ships will have to be paid out in some form of subsidy, also, as the vessels engaged in long-distance trading and making few entries in a year will need as much assistance as the vessel making many round trips in the same time. The foreign vessel will not have to increase its freight rate appreciably on account of the increased dues, so that the American vessel will not be able to recoup itself for the increased cost of operation on the long voyage by an appreciable increase in the freight rate; and this increased cost must be met by some form of subsidy. The details can be worked out, however, without much trouble, if the American Merchant Marine is recognized as a national problem and treated as a matter affecting the welfare of every citizen, as it should be treated.

We are interested in the modern cargo vessel as an efficient instrument for the carrying of the world's commerce and for the advancement of civilization, and also from a national viewpoint as a means of maintaining and protecting the independence of these United States of America. For this latter purpose, no minor sacrifice should be allowed to overshadow the great gain in independence which will result from our ownership and operation of a large fleet of modern cargo vessels.

The present status of American shipping is anomalous, as the United States Shipping Board has built during and since the war a much larger number of vessels than the country is able to operate advantageously. Ship operation is a very difficult subject, having many ramifications, and must be of comparatively slow growth if it is to be able to endure the vicissitudes to which it is more subject than the average business. The great problem before this country at present is not a lack of vessels, but a lack of experienced operators to manage the vessels. Any marine policy which overlooks this fact is doomed to failure. The difficulty of the task, however, should not deter us from tackling it in earnest, and the nation which bore the honors in shipping a century ago is doubtless able to repeat its performance at the present time.

AMERICA'S PETROLEUM PROBLEM.*

BY

J. O. LEWIS,

Petroleum Engineer, Consulting Engineer, U. S. Bureau of Mines.

THE topic assigned me for this evening's discourse is "America's Petroleum Problem."

This is indeed an important subject and one in which each of us should take personal concern. America's petroleum problem has extended beyond her own borders and cannot be considered as peculiar to herself, but is inseparably involved with the world's petroleum problem. The disposition of the world's oil resources has occupied much attention in recent journalism, both here and abroad. Few of us realize to what an extent petroleum is occupying the thoughts of the world's statesmen. It is a subject which has thrust itself prominently among the problems heritage from the war which now await the world's solution before the dreams of a lasting peace can be made true. It is now one of the chief subjects of international discourse and forms one of our most vexing problems in our relations with Great Britain, France and Mexico.

The sudden prominence into which petroleum has recently been thrust is largely a result of the disclosures of the great war, which caused every people to take stock of its needs and resources. The war provided tests under conditions which showed in unmistakable manner that petroleum had become one of the essentials of modern warfare and industrial life. As the war progressed, the needs for petroleum became more strikingly evident and in large part shaped the policies and strategies of the contending nations. Germany, with only limited oil resources, soon discovered that she must obtain oil to survive, and the drives into Roumania and Galicia were undertaken largely because more oil was needed. England's policies in the Near East, where she was accused of frittering away her resources in unessential military adventures, were largely shaped by the desire to protect her Persian oil fields and to acquire hold on the vast potential oil resources

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 27, 1921.

of Mesopotamia. Later an English force unexpectedly appeared in the Baku oil fields on the Caspian Sea when Russia passed under the control of unfriendly hands. Even before truce was declared on the European battlefields, England and France began to put into operation plans which had been laid during the war for acquiring possession of oil resources.

The conviction that oil is a vital necessity, both for commercial development and for military protection, was driven deep into the consciousness of every nation, and every nation, as soon as it could detach itself from the most pressing problems of the war, began to take stock of its needs and resources. The desire to fortify its future by adequate reserves of petroleum is to-day an active element in the policy of each forward-looking nation. It so happens that this country, besides being blessed with abundant oil supplies, has also been most forward in developing her own oil fields and extending the use of petroleum products. At the present we are producing more oil, consuming more oil, importing more oil, and exporting more refined oil than all the other nations combined, and were we to shut our eyes to the future we might say that we are so far ahead of the other nations that concern seems foolish.

Unfortunately the present situation is not a true gage of the future. Our position is more like a spendthrift who seemingly is possessed of unlimited wealth, but who is really squandering both capital and interest. We have been very active in seeking out and developing our oil resources, whereas the rest of the world remains hardly touched. Our energy in quickly finding and obtaining our oil has misled us in regard to our own reserves, so that when we face the future, realizing that to keep up and advance our standards of living we require more oil than any other people, we see that it is important that we be not excluded from the undeveloped oil reserves of the world.

It is not my purpose to discuss the political aspects of the petroleum problem so much as it is to endeavor to set up a background against which you may see America's position and needs. There has been much confusion in the public mind because of the diverse opinions expressed and because of the seeming anomalies involved in the situation. I realize that my opinions do not fully accord with those of some others, so in giving them I shall endeavor to give my reasons also. Your secretary has thought that perhaps the position of Chief of the Petroleum Division,

Bureau of Mines, which I recently occupied in the government service, might make such information and opinions as I was free to give you a matter of interest, and I am therefore happy to meet his desires to the best of my ability.

Before I enter into the main part of my subject, I should like to have you consider to what an extent petroleum has entered into our present manner of living. We have reached our modern civilization through progressive conquests of the natural mineral resources. Our progenitors first learned how to use the flinty stones and then to reduce copper, tin, gold, silver and lead from their ores, but it was not until the metallurgy of iron was developed were we able to construct machinery and to make energy serve our purposes. For a source of energy we have used coal and with it the wonders of our day have been done. Coal and iron have provided the foundation upon which science has built the intricate structure of industries of our day.

It has been said that each American is fifteen men—himself and fourteen who serve him. This means that by his resourcefulness the American has multiplied his capacity for producing by fourteen times through the use of machinery. Each of us produces as much as fifteen men could do with their hands and consequently each of us may consume as much as fifteen men doing only manual labor. This fact is the foundation of our superior American standard of living, for we work shorter hours, yet have far more than any other people, for no other people has at command the forces of nature to a like extent. We are a nation of masters, not of servants; we do not battle nature constantly for a meagre existence, but have subjected nature and have compelled her not only to yield us our bare existence, but to yield us comforts and luxuries. Yet we are not satisfied, but are continually striving to add to our retinue of servitors.

Of the servants of man, petroleum is one of the most recently acquired, yet is one of the most essential as well as unique. With the products of petroleum we have been able to conquer where before we dared only to hope. The products of petroleum are pervasive throughout the whole structure of our present existence to an extent not realized by many. To those who are informed the possibility of a loss of this servant gives a feeling of consternation. Automobiles, trucks, tractors, airplanes, motor ships, these and many other machines of peaceful and martial use are

commonly known to feed upon petroleum products—but how many stop to think that their automobiles and every other machine, no matter whence its power comes, would be refractory servants indeed without the lubricating oils from petroleum? Friction has always been the thief of power and the engineer must battle incessantly against it. Were it not for petroleum lubricants every moving part would become static. Our whole industrial life would stop.

It is difficult to realize how recent has been the acquisition of petroleum. It has been within the last sixty years. Yet mention of petroleum goes back into remote antiquity. Tars from oil seepages were used in ancient Egypt, and in Babylonia the mud-brick buildings were cemented and protected by natural pitch. The fire-worshippers of Persia, one of the oldest religious sects, worshipped the eternal fires of the gas springs in the southern Caucasus, where the Baku fields were discovered in the last century. Throughout the lands from whence came our culture and religion seepages of oil and emanations of gas abound. In Persia, Mesopotamia, Palestine and in Egypt the geologist of to-day is finding among the ruins of ancient civilizations the oil fields from which the modern civilization will be supplied. Perhaps there is no more striking picture of the material progress of our times than of the modern scientist finding this magic fluid deep under the ground across which countless ages have marched unwittingly.

The modern history of petroleum dates from the Drake well, drilled in 1859 near Titusville, Pennsylvania. From Titusville prospecting was carried northeast as far as Olean, in southwestern New York, and southwest through parts of Ohio and West Virginia into Kentucky. Until 1876 this district, known as the Appalachian oil field, produced all of our oil. From 1876 to 1886 it produced over 95 per cent. of our oil, and up until 1900 it was producing over half of our oil, yet to-day it yields less than a tenth of our production.

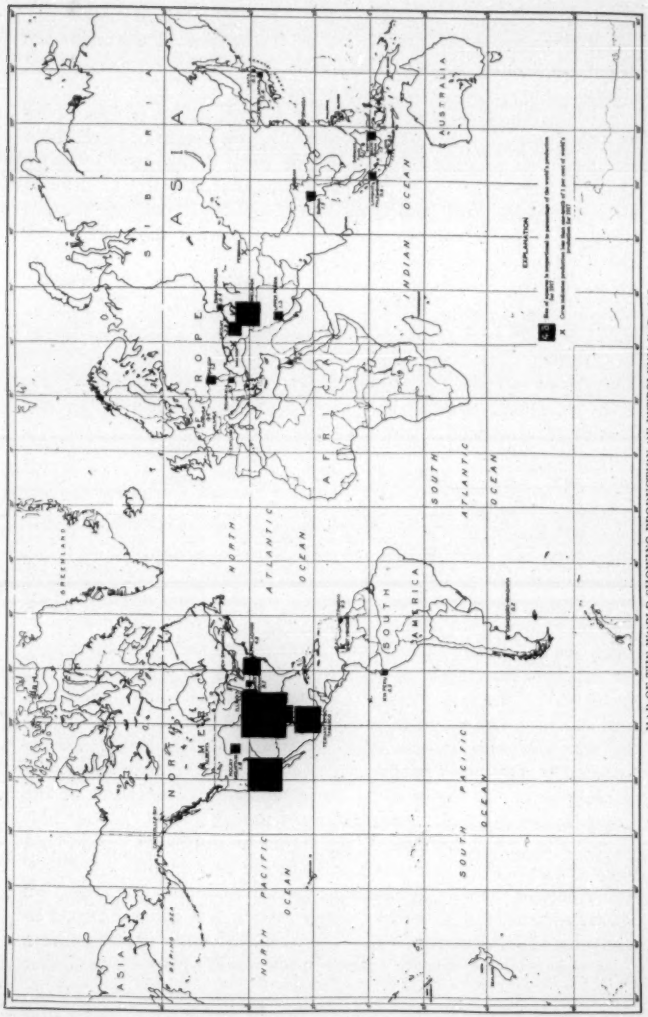
After the Appalachian district was discovered oil was found in the Trenton Line fields in western Ohio and eastern Indiana, then in succession in California, Texas, Kansas, Louisiana, Oklahoma, Illinois and most recently in Wyoming.

At the present time the States of California, Texas and Oklahoma are the leaders and produce about equal amounts, with

Kansas fourth and Louisiana fifth. The greatest oil district extends throughout the Carboniferous formations of the Mid-continent, including Kansas, Oklahoma, and northern and central Texas. This district yields half of our oil.

After the discovery of oil in the United States it was found in many parts of the world, and there are few countries now which do not either produce oil or in which there is not good evidence that oil does exist. The United States was the first to develop the modern industry, and with the exception of four years, from 1898 to 1902, has kept the lead to the present day. In 1919, the last figures available, the productions of the leading countries were: United States, 377,719,000; Mexico, 87,073,000; Netherlands, East Indies, 15,428,000; India, 8,735,000; Roumania, 6,614,000; Poland (Galicia), 6,054,000; Peru, 2,616,000; Japan, 2,175,000; Trinidad, 1,841,000 Argentina, 1,183,000; Russia, 25,498,000; Persia, 10,018,000; Egypt, 1,487,000; and other countries, 2,112,00; making a total of 548,492,000 barrels for the world, of which 68.7 per cent. was derived from this country. The geographical distribution of the world's production can best be gained from the excellent chart prepared by the United States Geological Survey.

The chart showing the distribution of the world's oil production does not show where the oil's future production is to be obtained nor where the world's oil will be needed. At the moment the United States produces about two-thirds of the world's output and consumes nearly three-fourths. Other peoples have not developed the appetite for petroleum products that we have and it may be expected that, great as will be the growth of demands in this country, the needs of other nations will grow still more rapidly and insistently. The enviable prosperity of our population is caused by supplementing human labor by machine to a degree not yet reached by any other people, and the fact that we consume nearly three-quarters of the world's oil production is indicative of the comparative degree of subjugation of nature's forces to our bidding. But in any thoughts of the future we must bear in mind not only the growth of our own needs but the even greater growth of other nations' needs. We cannot expect to maintain our proportion of two-thirds of the world's output, much less can we expect to consume three-quarters of it. The people of other nations have a just right to insist that they share in the world's resources and that



MAP OF THE WORLD SHOWING PRODUCTION OF PETROLEUM FOR 1917

PREPARED BY THE U.S. GEOLOGICAL SURVEY

FIG. 1.

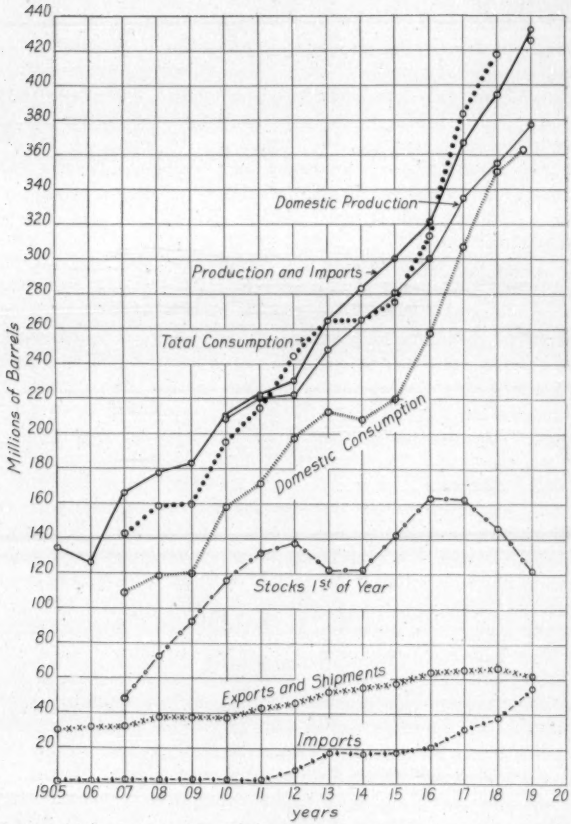
they obtain the fair proportion of their needs. The accusation made against us by some writers across the water that we seek to perpetuate our present overwhelmingly dominant position is manifestly absurd. On the other hand, a policy of absolute exclusion of us from the commercial development of resources under foreign political control—some territories being mandates—is not one which we can countenance with equanimity. There have never been any restrictions to the participation of foreign peoples in our petroleum resources. We should not seek monopoly, neither should other nations seek monopoly nor to build up a Chinese wall around their resources, for these would be, it seems to me, unfortunate policies, which will lead to retaliations and discord among nations.

There has probably been no new resource the demands for which have increased at such a rate as with petroleum. The increase has been relatively greater in recent years, for with the advent of the internal combustion motors applied to automobiles, cars, trucks, tractors, airplanes, etc., the utility of liquid fuels have come strikingly to the fore. Great as has been the growth of these devices, their development is very plainly still at an early stage, both as to the mechanical perfection of the oil-using machines and as to the adoption of these devices into our economic structures.

As sources of power and heat the liquid fuels have peculiar advantages, of which there is growing appreciation. It is particularly adapted for small power units, more especially for automotive purposes, either on the water, under the water, on land, or in the air. The field for the pleasure car has been well developed in this country, but the utility of the truck has untold possibilities in short-hauled transportation, not only in our industrial but in our farming and mining centres. It promises to work wonders in solving transportation problems, not so much in supplanting the railroads on long hauls, but as their accessories in gathering and distributing on short hauls, which is the most efficient use for the truck and the least efficient for the steam road.

As small power and motive units on the farm, petroleum-using motors promise to go far to solve the farmer's labor problems. To-day our farmers are the greatest producers in the world per man, though not per acre, yet the farmer has not had his share of our fourteen mechanical servants. With the auxiliaries made

FIG. 2.



Production, imports, stocks, exports and consumption of petroleum in the United States as shown by the Bureau of Mines.

possible by petroleum products, it would seem as though the farmer might have at his disposal the labor-saving devices of which he is most in need.

One cannot contemplate the future of the airplane without being carried away with visions. It may not supplant the means of transportation of to-day in as many ways as some of its early advocates believed, but it has proved universally true that new inventions tend, perhaps, even more to extend into new fields of usefulness not previously at man's disposal than to supplant previously used devices. For the airplane, its peculiar features of speed beyond all former conceptions and its capacity for straight-line travelling, independent of water, plains, mountains, roads, or railroad tracks, place it in a class by itself and give us a device of a kind not previously known, the use of which will call for new conceptions of transportation.

On the sea, fuel oil has unique advantages. Our Shipping Board has claimed repeatedly that only by fuel-driven ships would we be able to overcome the other advantages enjoyed by other maritime nations.

The subject of our future needs cannot be discussed without consideration of the military features. The great war demonstrated in unquestionable manner that petroleum is essential in modern warfare—one of the things without which a nation is hopelessly inferior. The modern army moves in trucks and automobiles and on small railroads using gasoline engines. The big guns are mounted on tractors. Tanks are one of the most effective machines of modern warfare and the airplane is absolutely essential. On the sea, the submarine is possible only with liquid fuel and the fighting ships are inferior without oil fuel. Even the great dirigibles for both land and sea will use in the next war helium gas supplied from our oil fields. Recently the papers reported that in sham battle the British fleet was demolished in half an hour by the air fleet.

Thus for as long as it is necessary to guard our interests at home and abroad, adequate petroleum supplies are essential for our protection.

I have dwelt somewhat at length on these matters relating to the utility of petroleum and our future needs because I believe that petroleum is one of our most useful agents and one in which every individual in this country has a personal interest. I believe

that it is capable of extending our capacities far beyond their present scope and will place at our disposal many more than the fourteen mechanical servitors which we now are said to have. Our needs, therefore, are not only to retain these fourteen servants, but to employ in the future the others which adequate petroleum supplies will give us.

I have pointed out along what lines our needs are trending. How much they will be I cannot say. It would seem as though there were no limits to our capacity for absorbing petroleum supplies and that demand is therefore the same as supply—in other words, our needs are what we can obtain. The question then becomes—looking not at the immediate future, but over a long term of years—how much can we obtain and how can we best use what we get?

In considering our oil resources and whether or not they are adequate, we should keep in mind the fact that it will not suffice merely to maintain our present production, but that it is desirable that production be greatly increased in order that we may fully realize upon the benefits to be derived from ample supplies. Yet at the same time we should be provident and far-sighted. The future should not be sacrificed too much for the present, nor should present supplies be conserved for a far distant future whose needs we cannot know, for in these days of wonders a generation or two hence may have powers which will make petroleum of little concern to them. Petroleum supplies should be sought and developed to the extent that this generation can use them wisely and conservation of our resources should be applied, in my opinion, with sane providence and not hoarded for an indeterminant future for the use of a generation which perhaps will not need them.

Until recent years our country produced more oil than we used and we exported more than we imported. We had developed our fields faster than we had developed uses for petroleum. But now we import more than we export, and no longer are we a self-sufficing nation. It is true that production has increased in recent years—increased tremendously—but our consumers have found ways of using oil faster than our producers have found new supplies, and were it not for the opportune discovery of the extraordinary Mexican fields this country would have experienced great stringency during the past several years. Whether or not the supplies underground are as great as our optimists hope, or as

little as our engineers estimate, no one disputes the fact that our production must be supplemented to a larger and yet larger degree in future years from foreign supplies. America's petroleum problem has therefore taken on an international aspect.

In considering our domestic resources I desire first of all to take stock of the underground reserves in our oil fields and to leave the questions of substitutes till later in my discourse.

In respect to our underground supplies there are two schools of thought. The opinion of the practical oil man, or the man who is strongly interested financially in oil, is usually very hopeful. The practical oil man usually believes that there is no way of estimating oil supplies underground; that in the past new fields have been found as needed, and so in the future there will always be new sources of supplies discovered concurrently with our growing needs. His is an abiding optimism, frankly disclaiming proof and denying that proof either one way or the other is possible.

The other school is that of the engineers, particularly technical men in the employ of the government. They have endeavored to reduce the estimation of oil reserves to an engineering basis, and while disclaiming great accuracy yet confidently believe that their figures are a useful gage of our resources and do show about what we may expect in future.

It is not possible to go into a detailed discussion of the basis of such estimates, and I will content myself by saying that, taken as a whole, these engineering estimates are reasonable probabilities, are sincerely made, and represent the best that can be had, and it would be folly to ignore them for nothing more substantial than vague optimism. It might perhaps be pertinent to point out here that the large increases in production obtained in recent years, which have sustained the oil man's optimism, are primarily due to the great success in finding new fields by those geologists whose estimates of future production the practical oil man treats with so much skepticism. It is entirely possible, though in my opinion unlikely, that, upon the basis on which made, the estimates of the geologists may be much too low, but again they may be too high. In any event it gives us something sufficiently dependable upon which to base our policies for the future.

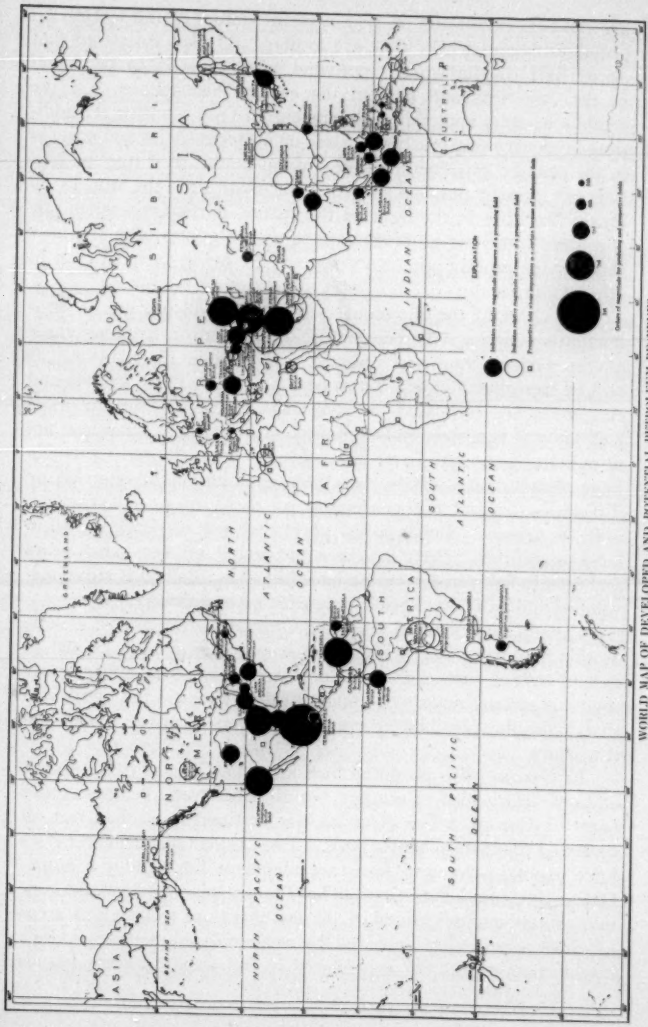
The opinions of the first school are of course not reducible to figures. The United States Geological Survey has estimated our

petroleum supplies as over 40 per cent. exhausted, and that were it possible—which it is not—for these reserves to be drawn upon continuously at the present rate, they would last not two decades.

Here is a picture which, set off by itself, is indeed a gloomy one, but I hasten to add that though we should not pass this by without learning the lesson it teaches, we are not in such desperate plight as one might believe at first sight. The estimates of the Geological Survey are based on the methods of oil recovery common until the present time, but there is excellent reason to believe that by methods recently applied, the recovery of the oil, held by capillary forces in the multitudinous pores of the oil sands, will be greatly increased. For myself, I believe recovery in the past has been less than 20 per cent. of the oil sand contents, and I am of the opinion that recovery may be increased by at least half, and perhaps by as much again as is now being obtained. This latent resource and the oils which may be derived from coals and bituminous shales, together with the known and probable oil reserves of other countries which have not been so intensively developed, make a picture not so dismal.

It has been found in recent years that oil is widely distributed and is likely to be found wherever there are large areas of unaltered sedimentary strata. In any region where oil occurs there is most always visible evidence in the nature of seepages, tars and gas springs—sometimes these surface showings are very plain, as in California, Mexico, Trinidad, Russia, and elsewhere, but sometimes they are not so evident and are not reported until close investigations are made by those experienced in oil finding. Since oil has become of such universal interest, reports previously neglected are being investigated, and there is now going over the surface of the globe an intense search for evidences of oil regions. Many such regions have been discovered and many are now being tested. Although information on the extent and value of these deposits is still meagre, there is enough to indicate that vast fields exist in known parts of the world and that the possibilities of the as yet undiscovered fields are perhaps still greater.

The world's petroleum resources was the subject of a recent paper by Dr. David White, chief geologist of the United States Geological Survey, who probably more than any other man is qualified to write on this subject. Doctor White has made estimates which, though admittedly of the most preliminary nature,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NORTH PACIFIC OCEAN
SOUTH PACIFIC OCEAN
EXPLANATION
WORLD MAP OF DEVELOPED AND POTENTIAL PETROLEUM RESERVES
PREPARED BY THE U. S. GEOLOGICAL SURVEY

FIG. 3.

are the best extant and do give a useful picture of the world's oil possibilities and where they are located. He has estimated that about half of the world's potential production is to be found in the Americas and half in the eastern hemisphere. Of the world's reserves something like one-eighth (not counting the additional recovery previously discussed or oil from shales and coal) is in the political possession of the United States, so it may be seen that our present position of producing two-thirds the world's oil means but little in the light of the future, particularly when one considers what our proportionate needs are going to be and how much more rapidly our own resources are being depleted than in other countries.

The chart of the oil resources of the world—not present production—is perhaps the best picture of the comparative magnitude of the various countries' reserves and of their distribution. It will be seen that Mexico, Venezuela, Colombia, Peru, Bolivia and Argentina are estimated to have large reserves. Mexico, as is well known, is wonderfully supplied, and enormous quantities are now being imported from her fields. Venezuela and Colombia have demonstrated fields, but their exploitation is retarded by difficulties beyond the conception of those of us not familiar with the tropics. But in a few years they will be supplying oil in large quantities. Peru has been producing oil for many years and certain fields in Argentina have likewise. Bolivia is still undeveloped and will be accessible only with great difficulty.

Canada has produced oil in the Ontario district almost as long as this country. For many years seepages have been known to extend over a vast area in the northwest provinces, and recently there have come reports of important discoveries in the Far North that make the possibilities even better than accorded Canada on this chart.

In Europe oil is produced in Roumania, Galicia, Italy, Alsace, and near Hanover in Germany, but oil is believed to exist in other parts of Europe. The Near East is destined to be the great oil centre of the eastern hemisphere. The Caspian district and Persia have prolific fields and signs are abundant throughout Mesopotamia, Syria and Palestine. The Transcaspian district also contains abundant indications of oil and there are tremendous areas of Siberia and China covered by unaltered sedimentaries which might contain oil. Oil is produced in India and on many islands

of the East Indies; oil is also found in Japan, Formosa, and Saghalien. Indications of oil are abundant in the Philippines, oil has been found in small quantities in New Zealand, but as yet not in Australia.

In Africa oil is found in Egypt and will doubtless be found in Algeria. Oil is also known to exist in Portuguese Angola, but the vast area of Africa remains as yet practically unexplored by the oil geologist, and undoubtedly many fields now unsuspected will be found in future.

It is evident that this world is not in danger of running out of oil supplies overnight, and that if the political and commercial situations affecting the oil supplies of the world are worked out with reasonable equity, we should have oil for as long as the future needs can be reasonably foreseen. We may not have all that we desire—perhaps not all that we could use, but probably all that is needed to supply those demands for which satisfactory substitutes cannot be found.

The realization of the desired end will not be without difficulties; there will certainly be keen commercial and political rivalries, as indeed there is to-day, but if we apply ourselves to the problems involved they will almost certainly be solved. But if we do not apply ourselves opportunely, then I am of the opinion that we shall find ourselves at keen disadvantage in future as compared to more enterprising nations, and that this generation will in later years be blamed for its improvidence. The efforts should be made not only in keeping foreign supplies open to our nationals, but in developing every possible domestic resource which promises to supplement the oil supply.

More than any other natural resource, petroleum has gripped the consciousness of the peoples of the progressive nations. It has everywhere proved a more vexing problem in the disposal of ownership rights to the individual by the nation than with any other mineral. It is unique in its nature and in its mode of occurrence, and has therefore been treated as a thing apart. More attention has been given to nationalizing it and it has been considered the peculiar property of the state more than any other natural resource. This trend of thought—to consider the petroleum resources the property of the nation—has been greatly accentuated by the lessons of the war; thus we find England, whose dominant thoughts have always been the individualism of the citi-

zen and free trade, going far in nationalizing oil resources, in excluding other nationals from her colonies, and of actually participating in a controlling way in an oil company competing on a grand scale in the oil industry throughout the world.

When one considers England's peculiar military and commercial position, one can readily appreciate England's concern in obtaining adequate oil supplies. Her present production is but a few per cent. of the world's output and is not to be compared with ours. That England is forced to take steps necessary for self-protection must of course be conceded, but whether the steps which have been taken are wise and whether they constitute infringements on the rights or interests of others, is quite another matter.

The efforts of our government to remove discriminatory policies and to combat the tendencies towards exclusiveness in petroleum resources has centred around the acts of the British and Mexican governments largely because they were in position to affect our interests most seriously. It is perhaps unfair to couple the two governments in the same sentence, but they both are parts of the same general situation. There are certain interests which look upon the Mexican situation as *the oil problem* and others who think of the British situation as *the oil problem*, but as a matter of fact both should be considered as only features of *the oil problem*, for the same tendencies in various forms are displayed in policies in effect or under consideration by France, Russia, Japan and the countries of Latin America.

It is hardly necessary to detail how these tendencies have been manifested in the acts of the interested government. They have taken the form of complete nationalization of petroleum resources by some governments, of restricting development of resources to the nationals of the country, of various degrees of restrictions and discriminations on aliens and of active governmental participation in the oil industry, of which the Anglo-Persian Oil Company, in which the British has controlling interest, is the best example.

The Petroleum Policy of the British Government has been actuated primarily by her special situation. Some years ago England discovered that oil made a far superior fuel than coal for naval and merchant marine uses, and to such a degree that the Admiralty determined to construct an oil-burning navy, despite the fact that coal could be obtained at home, whereas oil must be

brought overseas and could not be obtained in sufficient quantities from even her own colonies and possessions. This situation influenced the Admiralty to take the unprecedented step of embarking in the oil business. The Anglo-Persian Oil Company was formed in partnership with a large British oil company to prospect and exploit a concession of half a million square miles in Persia where, after several unsuccessful ventures, prolific oil pools were opened up shortly before the Great War.

Since the war the Anglo-Persian has been greatly strengthened financially, and its activities have been extended throughout the British Empire. In Australia partnership corporations have been formed with the Commonwealth, which are practically monopolistic. Elsewhere there is evidence of activities which seem to make certain commercial competition between our larger oil companies doing business abroad with the Anglo-Persian. It need hardly be pointed out that such commercial rivalries, when one party is a government, are likely to make many delicate situations which will be fruitful of discord between the two peoples. Our government apparently views this situation with apprehension, for while England is doubtless within her rights, yet the exercise of these rights in this manner would seem to be an unfortunate precedence that is likely to make obstacles in working out that international comity which both peoples desire.

Many of the acts of various governments about which this country is concerned are also within the internationally recognized rights of the nations, yet the exercise of these rights seems to be unfortunate. We have the same rights, but we have never exercised them, nor do we now, yet we may be compelled to do so for self-protection. In England the petroleum policy of the government—particularly its partnership with the Anglo-Persian—has been criticized in Parliament largely because it may lead to international troubles, but the venture in Persia, by reason of the exceptional value of the discoveries there made, has fortified the proponents, and it would seem that the policy is to be pursued with increased vigor.

Although many of the acts and policies to which this government shows concern are clearly within the recognized rights of the nation, others are contrary to international usage, or to diplomatic understandings. The Mexican situation hinges around what is said to be in effect an attempt at the confiscation of vested rights

acquired legally by our citizens under the laws of the country as they then were. The partitioning of the oil rights of Mesopotamia between England and France and of Asia Minor between England, France and Italy through the so-called San Remo and tripartite agreements, respectively, are both against our traditional policy of the "open door" and against the plain understanding given to our representatives as to the nature of mandates when this form of political control was under discussion at Versailles.

These exclusive nationalistic tendencies our government has been combating these last two years particularly, and although our State Department has been under criticism, I think it can be fairly said that much headway has been made—more, in fact, than is apparent, for the greater accomplishments have probably been in preventing the perpetuation of war measures and the accomplishments of purposes under consideration than in recessions from positions already announced. Fortunately representations were started soon enough that many acts contemplated by foreign governments had not yet been put into effect. Yet much more needs to be done and the oil situation is yet to be settled. It is to be hoped that we shall not be compelled to retaliate and exclude other nationals, to embargo petroleum exports, or for the government, directly or indirectly, to get into the oil business.

Before leaving this subject I would like to call your attention to a need of our national government which the oil situation has disclosed. Our government is perhaps better equipped with technical bureaus than any other government, but there has been in the past a lamentable lack of coördination between the various agencies of the government. Fortunately steps were taken during the war for making available useful information from one department to another. The oil situation illustrates the value of this move, for it was called to the attention of our Department of State by the technical bureaus and they supplied much of the necessary information upon which action has been based. There is, however, real need for a system for coördinating the activities of our many government agencies in such way that the utility of government as a whole may be increased. There has been much talk of duplication of efforts and functions in the departments. From my own experience I judge this to be more seeming than real. A greater need is the further development of agencies for seeing that the many activities of the government function as parts of

one large machine rather than of a multitude of small independent machines.

I have endeavored in this discourse to bring out how desirable for our continued prosperity are abundant petroleum supplies. The rate of our future growth will, to a very considerable extent, be determined by whether or not adequate petroleum supplies will be available when needed. If they are available, we shall have many more added to our fourteen mechanical servants, and we shall have more conveniences, more pleasures and an added degree of universal prosperity. The desired supplies of petroleum in future cannot be obtained from our own oil wells, which were adequate to the past, and we must therefore turn to other sources of supply, both home and abroad. This constitutes America's Petroleum Problem—how are we to obtain the necessary petroleum products that our growth be not stunted?

Like most big problems there is no single solution—the problem will, in my opinion, be solved by the combined effects resulting from several lines of attack. These can, however, be grouped into two broad phases—one, the maximum development of home resources; two, the securing of foreign supplies.

The foreign situation has, I believe, been fairly well covered. There is, in my opinion, oil supplies adequate to ours and the world's needs for an indeterminate time. The problem is to secure to ourselves our needed portion. Our efforts, therefore, should be exerted towards influencing foreign governments to do away with their exclusive policies and to let oil be developed under the normal course of trade, in which case I think it can be safely said that our oil companies will take care of the situation when foreign governments reciprocate our policy of the open door.

I would like to advance one more thought in regard to the foreign situation. At the present time we have many things to sell which Europe needs but cannot buy because the European countries cannot pay in gold or goods and their credits have been stretched to the breaking point. When a country sells more than it buys the time is reached when the difference must be invested by the creditor nation in permanent securities or resources of the debtor nation. This was the trade relationship between England and the debtor nations, and accounts for the tremendous sums invested by her peoples abroad. But we are new as a creditor nation and our people, generally speaking, are not experienced in foreign

investments and will not readily absorb them. Mining—more particularly—is, however, an exception. It would seem as though the undeveloped oil resources of England and France might be used as a basis of credits that would absorb millions—perhaps billions—of dollars in permanent investments which in turn would open up resources that would be sold back to us in future and thus help to equalize trade balances, yet curiously enough the one kind of foreign investment which would most attract our investors and would seemingly measurably improve exchange rates and trade relations, is shut off from us.

But even should the foreign situation be settled to our entire satisfaction, we should by no means neglect our domestic resources. We should do everything possible to stimulate the wise development of other sources of oil supply, from oil shales, coals, and of oil substitutes from organic materials. This should be coupled with developing methods of getting more values out of such oil as we now have through better methods of production, refining, of utilization, and by substituting coal and other fuels from the larger reserves where possible. The home situation is thus primarily a technical problem, whereas the foreign is primarily a diplomatic problem.

It is not my desire to go into details regarding the other resources which might be developed for oil. They may, however, be briefly outlined. From our oil fields I personally believe there may be obtained by new methods at least 50 per cent., and perhaps 100 per cent., more oil which formerly was left unrecovered in the sands. From oil shales far more oil can be obtained than from our oil wells. A very great quantity of oil products can be obtained from coals. From waste organic materials alcohol may be obtained to substitute for gasoline.

Together these latent resources constitute an enormous reserve awaiting the technical knowledge and the right economic conditions for development. It must be kept in mind, however, that, speaking generally, these resources are to a very great extent dependent upon higher prices for petroleum products. To a limited extent (with the possible exception of oil shale) all are being commercially exploited to-day, but the large-scale development necessary to supply any large proportions of our needs will come gradually as our technical knowledge is developed and as our unsupplied needs force prices upward.

Tremendous improvements can be made in the utilization of petroleum which will enable us to get far more use from the oil than is being done to-day. The principal uses of petroleum are for lubricants, fuel for internal combustion motors, illuminating oil, and oil for heating or steam raising. The greatest opportunity for economy in use is in the further development of motors for heavy oils. Half of the petroleum products are heavy fuels used for heat and steam raising. All, or nearly all, should be used for generating power in internal combustion motors, for by so doing experience has shown that three times as much power can be obtained than when the oil is burned under boilers.

Fuel oil is particularly adapted to marine use, and our shipping board has constructed something like three-fourths of its merchant marine as oil burners, but unfortunately as steamers. To my mind it is a fit subject of public inquiry why more motor ships were not constructed and what plans, if any, exist for changing these steamers into motor ships in future. The motor ship is a demonstrated commercial success and England is replacing the steamships sunk by the Germans largely by motor ships. The shipping board is the largest consumer of fuel oil in the world, and its steamships not only use more oil, but divert oil from other consumers and induce peroids of shortage and high prices which otherwise would not be so acute.

There has been so much talk recently of embargoing exports, of retaliatory measures and of holding the oil in the ground for our own future needs that these subjects should receive some mention. It seems to me that the petroleum situation calls more for constructive thinking than for obstructive thinking, and these various policies of inhibition, in my mind, should be considered only as unavoidable choices in lieu of more satisfactory solutions. We might unfortunately be compelled to take retaliatory steps if forced to do so by lack of reciprocity on the part of foreign governments, but, in my opinion, it should be done only in a sense of compulsion.

As for embargoing exports, that seems to me to be mainly based on very superficial reasoning. If we were not already importing more than we export, this might have a solider basis of justification. As things are now, we import from Mexico not only enough for our own needs, but also for re-export. We therefore get the profits from refining and selling this oil. If we

embargoed exports, the European nations which we now supply would purchase their crude from Mexico and refine it there or in Europe, and the net result would be that in the end we would have no more oil than before and would lose these extra profits besides incurring the ill will that would be engendered by such a course.

The embargoing of exports and retaliatory measures in general should, in my opinion, be considered only as means to an end—that is, for inducing reciprocity in petroleum. Such measures should not be applied except as a final means to gain this end, for, in my opinion, they are founded on unsound principles, and ultimately are likely to prove to our own and everyone's great detriment; for if we are going to need oil from other countries in future it would seem folly to set a precedent of refusing oil now that we have it to those who need it now, but who hold the keys to the future in their hands. Yet as a temporary expedient we could employ our present position to great advantage, for if we should cut off our supplies to foreign countries now, it would be exceedingly embarrassing to them, for it would take a number of years of concentrated effort before they could replace these supplies from their own resources. This applies particularly to certain qualities of lubricating oils which so far have never been obtained from other than certain American crudes. Such a course would therefore be a potent weapon, but one which surely we would not wish to employ unless our hand was forced.

In conclusion I may state, as my opinion, that I do not apprehend any long-continued oil famines. I believe that this generation, and probably many more generations, will have sufficient supplies of petroleum products. But it must be kept in mind that this statement applies to the broad view of the situation, and that temporary periods of undersupply are likely to alternate with periods of oversupply, for the oil industry is particularly liable to such fluctuations, because each year new fields, not heretofore known, must be brought in to make up for the declining productions of the older fields. Because of the uncertainty of discovering and developing such new fields when needed, there is always the possibility that the next year not enough new production may be found to meet that year's needs.

In so far as our government is concerned, it should do everything possible to stimulate the development of home resources and of the discovery of more effective ways of using our oil supplies.

This can be done by supporting technical investigations and by other proper means of encouraging the greater extraction of oil from our fields, the development of oil shales, of methods of retorting oil from coals, for obtaining substitutes from organic waste materials and for the discovery and application of more efficient methods of utilization. So far as the foreign situation is concerned, our government, if properly supported by public sentiment, should at least be able to modify the objectionable foreign policies which hinder our nationals from going abroad.

If we apply ourselves in time, I see no reason why America's Petroleum Problem cannot be solved, but I must also qualify my optimistic opinion by stating that this desired end will not be attained without effort on our part. America's Petroleum Problem, in my opinion, will not solve itself, but America must apply itself diligently to solve its Petroleum Problem.

Dilatation and Compressibility of Liquid Carbonic Acid. C. F. JENKIN. (*Proc. Royal Soc.*, A690.)—Compressibilities are tabulated for temperatures ranging from −37° C. to 30° C. At the latter temperature and under a pressure of 1100 lbs. per square inch the coefficient is .00114. At the same pressure the coefficient is only one-sixth as great when the pressure is raised to 1400 lbs. per square inch. The remarkable properties of liquid carbon dioxide will be seen more clearly when it is stated as follows: At 30° C. and 1100 lbs. per square inch an additional pressure of one pound per square inch reduces the volume of the liquid by more than 1 per cent. An approach to the critical temperature with the pressure maintained constant is always accompanied by an increase of the coefficient, while an increase of the pressure, the temperature being maintained constant, results in a lowering of the coefficient.

The table of dilatation likewise contains remarkable results. At 30° C. at 1100 lbs. pressure per square inch an increase of a single degree C. causes the volume to increase by .0517. For gases, not liquids, under normal conditions the corresponding quantity is .00366, or only one-fourteenth as much. So small a coefficient as that of gases was not found for liquid carbonic acid until the relatively low temperature of −30° C. was reached and then only at a pressure of 500 lbs. per square inch. The dilatations increase rapidly as the temperature rises and approaches the critical temperature; for example, it is about eighteen times as great at 30° C. as at −37° C., the pressure being 1100 lbs. per square inch in both cases, and also it changes greatly with changes of pressure.

The data furnished are the results of careful experiments by the Professor of Engineering Science at Oxford.

G. F. S.

Is the Atom the Ultimate Magnetic Particle? A. H. COMPTON and O. ROGNLEY. (*Phys. Rev.*, November, 1920.)—In 1915 K. T. Compton and E. A. Trousdale investigated the diffraction patterns produced by X-rays passing through a magnetic crystal when it was not magnetized and again when it was magnetized. They obtained a negative result. If the ultimate magnetic particle consists of a molecule or other group of atoms the magnetizing of the crystal with the accompanying rotation of the magnetic particles should bring about a different arrangement of the atoms within it, and this in turn should be followed by a change in the diffraction pattern. The failure to discover this change furnished a strong argument against the molecule being the magnetic particle. Is it, then, the atom or something even smaller?

The atom now, according to Rutherford, consists of a central nucleus with a resultant positive charge about which electrons are revolving. When a magnetizing field is applied to a crystal, the atoms, if they really are the magnetic particles, will turn about until their axes are oriented on the whole in a direction different from that previously maintained. Fortunately, this should produce a result capable of detection. The intensity of a beam of X-rays reflected from the face of a crystal is dependent upon the arrangement of the electrons with respect to the face. Any turning of the atom should therefore manifest itself by a change in the intensity of the reflected beam. It was such a change that the experimenters sought, but failed to find.

X-rays from the same target were divided; some passed to the right and were reflected from a crystal of rock-salt into an ionization chamber; others went to the left and were reflected by a crystal of magnetite into another similar chamber. These two chambers were joined to a quadrant electrometer so as to produce deflections in opposite directions. Adjustments were made until no deflection was obtained. Then the magnetization of the crystal was changed by an electromagnet. Changes in intensity as small as 1 per cent. could have been detected, but no such changes were observed. The applied magnetization was, however, sufficient to magnetize the crystal only to one-third of saturation. It seems that we can not regard the atom as the magnetic particle in consequence of the negative outcome of this experiment. We are thus seemingly reduced to the positive nucleus and to the electrons. Barnett's production of magnetization by mechanical rotation and Stewart's obtaining of rotation by magnetization are interpreted to show that the motion of negative electricity produces the chief part of ferromagnetism, and this rules the positive nucleus out. The authors, after a careful examination of the evidence at hand, draw the modest conclusion, "The magnetic properties of matter are due either to the nucleus of the atom or to the individual electrons. Auxiliary evidence, however, indicates that the electron is the more probable elementary magnet."

G. F. S.

HARMONIC OSCILLATIONS.*

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PART I. PREAMBLE ON STRUCTURE OF THE EQUATIONS.

INTRODUCTION.

Purpose of Treatment.—In the study of airplane stability one frequently employs the equations of harmonic motion, both linear and angular, and especially of damped harmonic motion. It is therefore useful to have the equations and properties of such motion presented in a form convenient for ready reference and application. Some of the more usual of such equations and properties are given in the present elementary treatment, prepared for the Bureau of Construction and Repair in its Aerodynamical Laboratory at the Washington Navy Yard. The text drawings were made by Mr. G. C. Hill.

Definition.—Harmonic motion in general may be defined as a movement whose acceleration is toward an equilibrium position and is proportional to the displacement of the moving object from that position. Such motion may be either frictionless or retarded by friction, say of the surrounding medium. A simple pendulum bob, for example, when making small excursions about its position of rest, executes harmonic motion, whether performing plane or compound vibrations, whether moving undamped in vacuo or damped in a fluid such as air or water; for, as is well known, its acceleration is always toward the point of rest and proportional to the distance therefrom. Similarly a torsion pendulum gently twisting about its axis performs harmonic motion.

A harmonic oscillation is called "free" when subject only to acceleration within the vibrating system; "forced" when accelerated from without. A free oscillation is called "damped" when impeded by friction or other deadening resistance; "undamped" when void of such resistance.

In this text the damping retardation is assumed proportional to the speed; the external acceleration is taken as either a constant or a sine function of the time.

* Communicated by the Author.

DEVELOPMENT OF THE HARMONIC EQUATIONS.

Equation of Damped Straightaway Motion.—If a moving particle is opposed only by a force proportional and opposite to its velocity, say the resistance of a fluid, it will pursue a straight path till brought to rest. And if ds be the travel in time dt, the damping force and acceleration may be written

$$R = -2ma\dot{s} \quad \ldots\ldots (1)$$

$$\ddot{s} = -2a\dot{s} \quad \ldots\ldots (1')$$

in which m is the mass of the particle, and $2a$ is for convenience taken as the "*damping coefficient.*" The quantity $2a$ is positive and may have any fixed value, depending on the opposing agency and the mass of the accelerated particle. It is in fact found from the force equation of the particle by dividing the coefficient of $\dot{s}$ therein by the mass.

Equation of Simple Harmonic Motion.—Similarly if the only opposing force, say an attraction or an elastic resistance, is proportional and opposite to the displacement from rest of the particle, its force and acceleration can be written

$$F = -mb^2 s, \quad \ldots\ldots (2)$$

$$\ddot{s} = -b^2 s, \quad \ldots\ldots (2')$$

in which b^2 is the "*displacement coefficient*" or "*stiffness.*" The quantity b^2 is positive and may have any fixed value, dependent on the restoring force and the mass of the accelerated particle. The movement represented by (2') is known as a "simple harmonic motion." It is, as will be shown by equations (9), (10), the rectilinear oscillation of a point whose acceleration is proportional and opposite to its displacement from rest.

Equation of Damped Harmonic Motion.—If the two foregoing forces act conjointly, the equation of motion becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = 0, \quad \ldots\ldots (3)$$

in which each term is an acceleration, and $\ddot{s}$, the resultant of the other two, is the actual acceleration of the particle at any instant. The complete treatment of this equation, therefore, comprises both undamped and damped free harmonic oscillations of a point in a straight line.

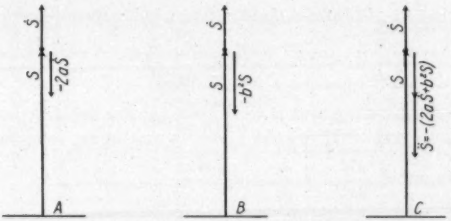
Graphical Composition of s, $\dot{s}$ and $\ddot{s}$.—Fig. 1 illustrates the relation of the various vector quantities in the foregoing equations. In sketch A the particle is seen moving in the positive

direction of s and opposed by a force proportional and opposite to s, which causes the acceleration $-2\,a\,\dot{s}$; in sketch B the particle moves from its position of rest opposed by a restoring force proportional and opposite to s, which causes the acceleration $-b^2 s$; in sketch C the particle moves from the point of rest opposed by both said forces, which beget the acceleration $-(2\,a\,\dot{s} + b^2\,s)$. The coefficients are written *2a and* b^2, rather than a and b, merely for simplicity in subsequent operations.

METHOD OF SOLVING THE EQUATIONS.

In order to divest of mathematical detail the analysis of the differential equations of motion, a preamble is here given on the usual method of integrating such equations.

FIG. 1.



Component and resultant accelerations of a particle performing rectilinear free harmonic oscillations.

Solution of the General Differential Equation.—The equations of free harmonic motion belong to the class known as linear differential equations with constant coefficients and second member zero, and have the general form

$$\frac{d^n y}{dx^n} + p_1 \frac{d^{n-1} y}{dx^{n-1}} + \ldots\ldots\ldots + P_n y = o, \quad \ldots\ldots\ldots\ldots (4)$$

where P_1, P_2,. . . . P_n, are constants.

To solve this by Euler's method, substitute e^{mx} for y. The first member of the equation then becomes $(m^n + P_1\, m^{n-1} + \ldots + P_n) e^{mx}$, which equals zero if

$$m^n + P_1\, m^{n-1} + \ldots\ldots + P_n = o, \quad \ldots\ldots\ldots\ldots (5)$$

This latter is called the auxiliary equation to (4). Since each

of its roots $m_1, m_2 \ldots m_n$, satisfies (5), $y = e^{m_1 x}$, $y = e^{m_2 x}$, etc., must satisfy (4). Hence the complete solution is

$$y = C_1 e^{m_1 x} + C_2 e^{m_2 x} + \ldots\ldots\ldots + C_n e^{m_n x} \ldots\ldots\ldots\ldots (6)$$

For example, to integrate

$$\frac{d^2 y}{dx^2} - 9y = 0,$$

the roots of its auxiliary equation,

$$m^2 - 9 = 0,$$

are 3 and -3. Hence the complete solution is

$$y = C_1 e^{3x} + C_2 e^{-3x}$$

Case I. Imaginary Roots.—In case the auxiliary equation (5) has imaginary roots, any pair of such roots, say $m_1 = \alpha + i\beta$, $m_2 = \alpha - i\beta$, where $i = \sqrt{-1}$, has the corresponding solution

$$\begin{aligned} y &= C_1 e^{(\alpha + i\beta)x} + C_2 e^{(\alpha - i\beta)x} = e^{\alpha x} (C_1 e^{i\beta x} + C_2 e^{-i\beta x}) \\ &= e^{\alpha x} [C_1 (\cos \beta x + i \beta \sin x) + C_2 (\cos \beta x - i \beta \sin x)] \\ &= e^{\alpha x} (A \cos \beta x + B \sin \beta x), \end{aligned}$$

in which $A = C_1 + C_2$, and $B = i(C_1 - C_2)$, are arbitrary constants, and are both real if C_1, C_2, be taken as conjugate imaginaries.

For example $\frac{d^2 y}{dx^2} + 8 \frac{dy}{dx} + 25 y = 0$

has the auxiliary equation

$$m^2 + 8m + 25 = 0$$

whose roots are $m_1 = -4 + 3i$, $m_2 = -4 - 3i$; hence the solution is

$$y = e^{-4x} (C_1 \cos 3x + C_2 \sin 3x).$$

Case II. Equal Roots.—If some of the roots of (5) are equal the corresponding terms in (6) coalesce. Thus if $m_1 = m_2$, then $C_1 e^{m_1 x} + C_2 e^{m_2 x} = (C_1 + C_2)\ e^{m_1 x} = C e^{m_1 x}$, and hence (6) lacks one integration constant of the n necessary for a complete solution. It can be shown, however, that if m_1 be a double root of (5), then $x\, e^{m_1 x}$, as well as $e^{m_1 x}$, is a solution of (4). And in general if m_1 is a root of the order p of (5), the equation (4) has the solutions $e^{m_1 x}$, $x\, e^{m_1 x}$, $x^2\, e^{m_1 x}$, $\ldots\ x^{p-1} e^{m_1 x}$.

For example, the equation

$$\frac{d^3 y}{dx^3} - 3 \frac{d^2 y}{dy^2} + 4y = 0$$

has the auxiliary equation

$$m^3 - 3m^2 + 4 = 0$$

whose roots are -1, 2, 2. Hence the complete integral is

$$y = C_1 e^{-x} + C_2 e^{2x} + C_3 x e^{2x}.$$

Similarly if the auxiliary of a 4th degree equation be

$$m^4 - 4m^3 + 10m^2 - 12m + 5 = 0$$

the roots are 1, 1, $1 \pm 2i$, and the complete solution is

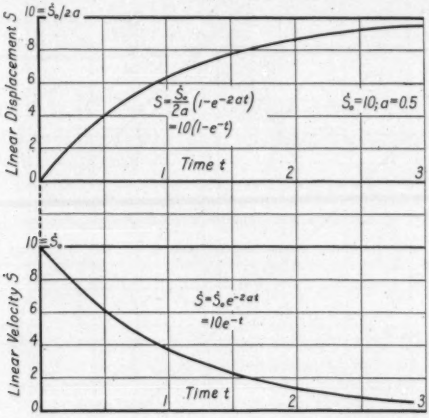
$$y = C_1 e^{x} + C_2 x e^{x} + C_3 e^{x} \cos 2x + C_4 e^{x} \sin 2x.$$

PART II. FREE OSCILLATIONS.

COMPONENT TERMS OF RECTILINEAR DAMPED HARMONIC MOTION.

Kinematics of Damped Straightaway Motion.—Equation (1′)

FIG. 2.



Damped straightaway motion of a particle subject to a resistance proportional to the velocity.

for damped straightaway motion gives, on integration for s and $\dot{s}$, the general values,

$$s = Ae^{-2at} + B$$
$$\dot{s} = -2aAe^{-2at}$$

in which A and B are constants of integration. And if the initial speed is $\dot{s} = \dot{s}_o$, when $s = o = t$, the constants are $A = -B = -\dot{s}_o/2a$.

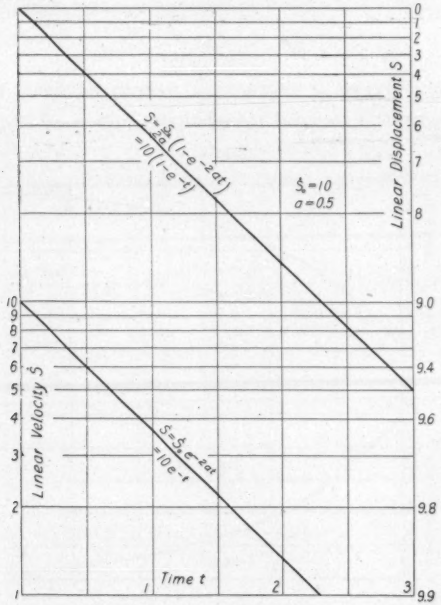
Hence

$$s = \frac{\dot{s}_0}{2a}\left(1 - e^{-2at}\right) \quad \ldots\ldots (7)$$

$$\dot{s} = \dot{s}_0 e^{-2at} = \dot{s}_0 - 2as \quad \ldots\ldots (8)$$

As t increases indefinitely e^{-2at} vanishes asymptotically; s approaches the limit $\dot{s}_0/2a$; and the speed $\dot{s}$ vanishes asymptotically.

FIG. 2'.



Damped straightaway motion of a particle subject to a resistance proportional to the velocity.

The motion is a species of *subsidence*, or a disturbance which dies out without oscillation.

The graphs of (7) and (8), in Fig. 2, and Fig. 2', illustrate how the travel s, of the particle, asymptotically approaches its limit $\dot{s}_0/2a$, and how similarly the speed dies away in infinite time, as

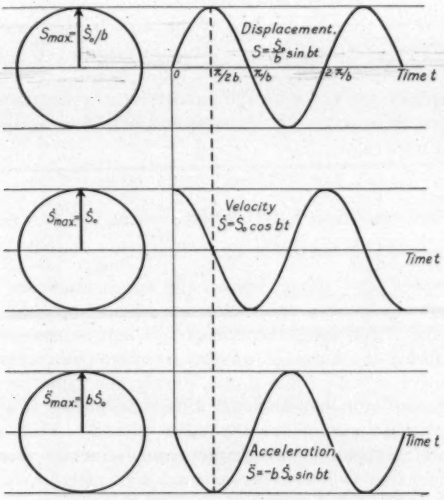
indicated by the exponential factor e^{-2at}. Such factorial expressions go by the general name of "*damping factor.*"

Kinematics of Simple Harmonic Motion.—Equation (2′) for simple harmonic motion gives, on integration for s and $\dot{s}$, the general values

$$s = A \sin bt + B \cos b\,t$$
$$\dot{s} = b\,(A \cos b\,t - B \sin b\,t)$$

in which A and B are constants of integration. If the initial speed is $\dot{s} = \dot{s}_o$, when $s = o = t$, the constants are, $B = o$, $A = \dot{s}_o/b$.

FIG. 3.



Simple harmonic motion, graphical elements of.

Hence

$$s = \frac{\dot{s}_o}{b} \sin b\,t \quad \ldots\ldots (9)$$
$$\dot{s} = \dot{s}_o \cos b\,t \quad \ldots\ldots (10)$$
$$\ddot{s} = -\,b\,\dot{s}_o \sin b\,t \quad \ldots\ldots (11)$$

These general equations for the displacement, velocity and acceleration of the oscillating particle at any instant, are plotted as functions of the time in Fig. 3.

(a) *Maxima.*—It appears both from this figure and from the equations that for $b\,t = o, \pi, 2\pi$, etc., the displacement s, and acceleration $\ddot{s}$, are o, while the velocity $\dot{s}$ has its greatest absolute value $\dot{s}_o, -\dot{s}_o, \dot{s}_o$, etc. Also that for $bt = \pi/2, 3\pi/2$, etc., the velocity is null, while the displacement and acceleration have their greatest absolute values; viz., $s_1 = \dot{s}_o/b$, $\ddot{s}_1 = -b\,\dot{s}_o$. The maximum displacement s_1 is called the "*amplitude.*"

(b) *Period and Frequency.*—It is seen also that as $b\,t$ changes by 2π, the quantities s, $\dot{s}$, $\ddot{s}$, run through a complete to-and-fro cycle, so that the *period* T of such a cycle, or oscillation, is

$$T = 2\pi/b \qquad (12)$$

That is T is the time of passage of the particle from any point of its path to that point again in the same direction. The *frequency* N of the oscillation is obviously $N = 1/T = b/2\pi$.

Incidentally the force on the particle at any displacement can now be written in terms of the mass and period or frequency. It is, by (2) and (12),

$$F = -\frac{4\pi^2}{T^2} ms = -4\pi^2 N^2 ms \qquad (13)$$

(c) *Phase and Epoch.*—If when $s = o$ in (9) $bt = \epsilon$, the equation becomes $s = \frac{\dot{s}_o}{b} \sin(bt - \epsilon)$. Then $(bt - \epsilon)$ is called the "*phase angle*" or "phase," and ϵ the epoch angle or "*epoch.*" This change of algebraic expression for s would produce in Fig. 3 a shift of the origin along the axis of t.

(d) *Added Motions.*—A number of simple harmonic motions $s_1 = C_1 \sin b\,t$, $s_2 = C_2 \cos b\,t$, etc., having the same period $2\pi/b$, can be imposed simultaneously on a particle, giving it a resultant simple harmonic motion of the same period. This statement is proved in textbooks on mechanics, and is merely recalled here as a reminder that such an expression as $s = (C_1 \sin b\,t + C_2 \cos b\,t)$ is a simple harmonic motion.

(e) *Projected Circular Motion.*—Simple harmonic motion may be represented as the projection, on the diameter of a circle, of the movement of a point speeding uniformly round the circumference. Thus in Fig. 4, if the point p moves with uniform linear speed $\dot{s}_o$, round the circle of radius $\dot{s}_o/b$, its angular speed is b; its angular displacement, or *reference angle*, referred to the horizontal radius, is $b\,t$ in time t; and its vertical displacement, speed and acceleration are obviously as given in (9), (10), (11).

Also the period of a complete cycle clearly is $2\pi/b$, as given in (12). Hence the kinematic properties, so far found algebraically, for simple harmonic motion, can be read from the *reference circle* whose radius is of length equal to the amplitude of said motion.

(f) *Energy of Simple Harmonic Motion.*—For a particle of mass m, at any displacement s, the force F opposing the motion, and the potential energy W, or work done against F during displacement from rest, are respectively

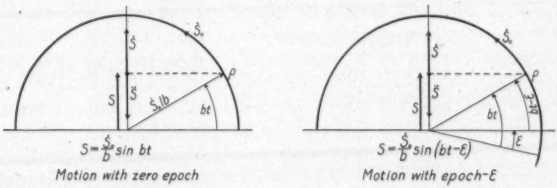
$$F = m\ddot{s} = -m b^2 s,$$

$$W = -\frac{F}{2} s = m b^2 s^2/2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

since the mean value of the reversed effective force causing the displacement is $-F/2$. But by (9) and (10), $\dot{s}^2 = \dot{s}_o^2 - b^2 s^2$; hence the kinetic energy, $E = m\dot{s}^2/2$, of the particle is

$$E = \frac{m}{2}(\dot{s}_o^2 - b^2 s^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

FIG. 4.



Simple harmonic motion as the projection of the uniform motion of a point on a reference circle.

Hence the total energy, kinetic and potential, of the particle is

$$E + W = m\dot{s}_o^2/2 = \text{constant}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

The mean potential energy throughout the period, $T = 2\pi/b$, is $W_m = \frac{1}{T}\int_o^T W\, d\, t$, which on writing, from (14) and (9), $W = b^2 m\, s^2/2 = \frac{m\dot{s}_o^2}{2} \sin^2 bt$, and integrating, gives

$$W_m = m\dot{s}_o^2/4, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

or half the total energy. So also the mean kinetic energy is $m\dot{s}_o/4$. Both these and the total energy vary as $\dot{s}_o^2$; also as the square of the amplitude or maximum displacement, which was shown to be $s_1 = \dot{s}_o/b$.

Reversed Simple Harmonic Motion.—If in equation (2) the

sign of b^2 be reversed, that is if the force and acceleration be directed away from the point of equilibrium, the equation of motion becomes on integration

$$s = A e^{bt} + B e^{-bt}$$
$$\dot{s} = A b e^{bt} - B b e^{-bt}$$

The first of these equations shows that the space increases indefinitely with the time, and always in one direction, that is without oscillation; the second shows that the speed increases indefinitely.

A motion that increases without oscillation is called a "*divergence.*" The displacement may increase indefinitely or it may asymptotically approach a limit. In the latter case it also answers the definition of a subsidence.

KINEMATICS OF RECTILINEAR DAMPED HARMONIC MOTION.

The General Integral.—Equation (3) for damped harmonic motion gives, on integration for s and $\dot{s}$, the general values

$$s = Ae^{\alpha t} + Be^{\beta t}$$
$$\dot{s} = A\alpha e^{t} + B\beta e^{\beta t}$$

in which A and B are constants of integration, and the roots of the auxiliary equation are

$$\alpha = -a + \sqrt{a^2 - b^2} = -a + r_1$$
$$\beta = -a - \sqrt{a^2 - b^2} = -a - r_1 \qquad \ldots\ldots (18)$$

If $\dot{s} = \dot{s}_0$ when $s = o = t$, the constants are $A = \dot{s}_0/2r_1$, $B = -\dot{s}_0/2r_1$. Hence

$$s = \frac{\dot{s}_0}{2r_1}(e^{\alpha t} - e^{\beta t}) \qquad \ldots\ldots (19)$$

$$\dot{s} = \frac{\dot{s}_0}{2r_1}(\alpha e^{\alpha t} - \beta e^{\beta t}) \qquad \ldots\ldots (20)$$

are the general values of the displacement and speed of the oscillating point in terms of the time and given coefficients a, b. The solution takes three forms according as a is less than, equal to, or greater than b; viz., as $r_1 = \sqrt{a^2 - b^2}$, is imaginary, zero or real.

Case I: $a<b$; Motion Periodic.—When r_1 is imaginary write $r_1 = ir$, where $r = \sqrt{b^2 - a^2}$, and (19) becomes, on using the values of α, β, in (18),

$$s = \frac{\dot{s}_0}{2ir} e^{-at}(e^{irt} - e^{-irt}).$$

Now substituting in this equation Euler's values,

$$e^{irt} = \cos rt + i \sin rt,$$

$$e^{-irt} = \cos rt - i \sin rt,$$

the imaginary i cancels out, and the displacement and speed are found in the form,

$$s = \frac{\dot{s}_o}{r} e^{-at} \sin rt, \quad \ldots\ldots (21)$$

$$\dot{s} = \dot{s}_o e^{-at} \left(\cos rt - \frac{a}{r} \sin rt\right). \quad \ldots\ldots (22)$$

$$= \frac{\dot{s}_o}{\cos \varepsilon} e^{-at} \cos (rt + \varepsilon), \text{ where } \frac{a}{r} = \tan \varepsilon,$$

$$= \frac{\dot{s}_o b}{r} e^{-at} \cos (rt + \varepsilon)$$

(a) *Plot of Factors and Product.*—The right-hand members of (21) and (22) consist each of the product of two factors, an exponential factor e^{-at}, and a harmonic factor. In Fig. 5 these factors and their product are plotted as functions of the time. The sketches show, what is clear from the symbolic expressions, that e^{-at} decreases asymptotically to zero as the time increases indefinitely, while each harmonic factor represents a curve of constant amplitude and pitch. The ordinate of the damped harmonic curve is the product of the coincident ordinates of the component curves, *i.e.*, the exponential and the simple harmonic, and hence dies away in an oscillatory manner to zero as the time increases indefinitely. The amplitude of the simple harmonic motion in (21) is $\dot{s}_o/r$, which when $a = o$ is $\dot{s}_o/b$, as given in (9) for undamped motion. Each amplitude is the radius of the corresponding reference circle.

(b) *Period and Reference Angle.*—From equations (21) and (22) can be found the time of describing each stroke of the damped harmonic, and the corresponding value of the reference angle $r\ t$. Starting with $s = o = t$, it appears from (21) that $s = o$ again in the successive times given by $rt = \pi,\ 2\pi,\ 3\pi\ \ldots\ n\pi$; that is the time of each out-and-back stroke is

$$T^{I} = \pi/r. \quad \ldots\ldots (23)$$

or the whole period is $T = 2\pi/r$. Also the time T^{II} for any single outstroke to where $s = o$ is given by (22) in the form $\cos(rT^{II} + \epsilon) = o$, or $rT^{II} + \epsilon = \frac{\pi}{2}$; whence

$$T^{II} = \frac{1}{r}\left(\frac{\pi}{2} - \varepsilon\right) \quad \ldots\ldots (24)$$

Multiplying (23) and (24) by r gives the reference angles. Hence from these equations the chief elements of displacement and time can be summarized as follows:

TABLE I.

Period of Harmonic Movements.

Movement	Duration t.	Reference angle rt
Out stroke	$\frac{1}{r}\left(\frac{\pi}{2}-\epsilon\right)$	$\frac{\pi}{2}-\epsilon$
Back stroke	$\frac{1}{r}\left(\frac{\pi}{2}+\epsilon\right)$	$\frac{\pi}{2}+\epsilon$
Out-and-back stroke	$\frac{\pi}{r}$	π
Complete cross stroke	$\frac{\pi}{r}$	π
Complete double vibration	$\frac{2\pi}{r}=T=\frac{2\pi}{\sqrt{b^2-a^2}}$	2π
Simple harmonic vibration	$2\pi/b=T_o$	2π

Ratio of last two periods $T/T_o=b/\sqrt{b^2-a^2}$

From the foregoing paragraph it appears that damped, like undamped harmonic oscillations, are isochronous, and that their period is to that of the undamped ones in the ratio $b/\sqrt{b^2-a^2}$. This ratio equals unity when $a=o$; and is infinity when $a=b$, or when the motion just becomes aperiodic.

(c) *Maxima of Displacement and Speed.*—By (21) for s maximum $\dot{s}=o$, giving $rt=\frac{\pi}{2}+n\pi-\epsilon$; hence $s=\frac{\dot{s}_o}{r}\,e^{-at}\cos\epsilon=\frac{\dot{s}_o}{b}\,e^{-at}$. For $\dot{s}$ maximum the reference angle is $rt=(n+1)\pi-2\epsilon$; hence $\dot{s}=\dot{s}_o e^{-at}$. Again since the multipliers of e^{-at} in (21) and (22) remain unchanged as t increases by any number of whole periods, or by $n\,T$, the ratio of the nth + 1 maximum to the first is $s_{n+1}/s_1=e^{-n\,aT}=\dot{s}_n/\dot{s}_o$. Hence the graphs of the equations

$$s = s_1 e^{-at'} \qquad (25')$$

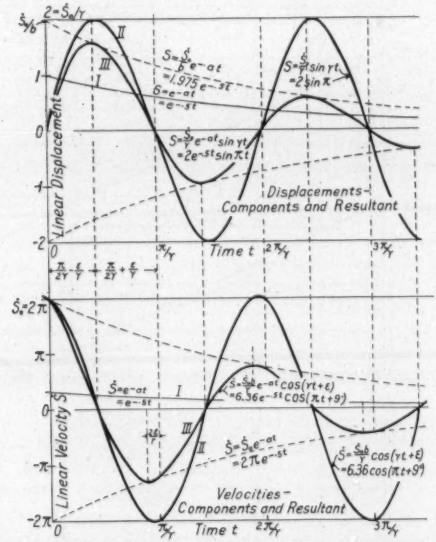
$$= \frac{\dot{s}_o}{b}\,e^{-at} \qquad (25)$$

$$\dot{s} = \dot{s}_o\,e^{-at} \qquad (26)$$

where t' is the value of t for the first maximum s_1, are curves passing through all the maxima points respectively of s and $\dot{s}$, as

shown in Fig. 5; for t being continuous assumes in turn all the discreet values of $n\,T$, whereupon s and $\dot{s}$ assume all the values of s_n and $\dot{s}_n$ respectively. It may be noted from (25) and (26) that the successive maxima of each curve (21) and (22) form a geometric series whose ratio is e^{-aT}, or that the nth amplitude is $s_n = \frac{\dot{s}_0}{b} e^{-anT}$. It is worth observing also that (25) and (26)

FIG. 5.



Displacement and speed in the periodic damped harmonic oscillation. I and II are components of III. The exponential curves cut the crests of the damped harmonic curves.

represent curves of discreet points, *i.e.*, wave tops, when T is substituted for t. On semilogarithmic paper (25) and (26) plot as straight lines, whose slopes are equal to a, as shown in Fig. 6.

For interpreting stability equations it is useful to note from (25) that $s = s_1/2$ when $a\,t = \log_e s_1/s = \log_e 2 = 0.693$; that is, the time of damping to one-half amplitude is

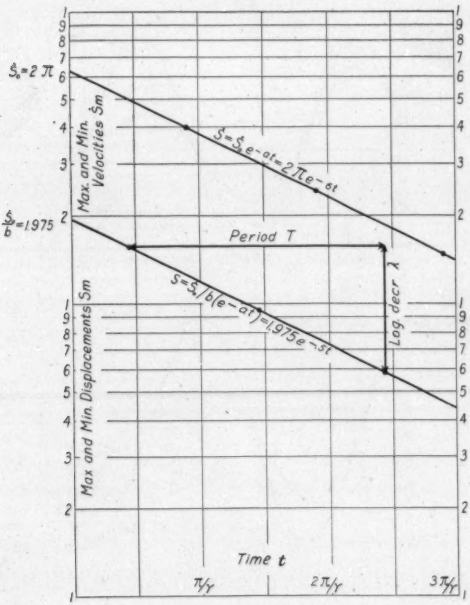
$$t = 0.693/a \qquad (27)$$

(d) *Logarithmic Decrement.*—From (25) one derives

$$\log s = \log s_1 - a\,t \qquad (28)$$

a linear equation in t, whose straight-line graph, as in Fig. 6, is useful in plotting oscillation data to show the rate of decline of the amplitude. In general the decrement of $\log s$, or $\log s_1 - \log s =$

FIG. 6.



Maxima and minima of displacement and speed in periodic damped harmonic oscillation. Circles mark the maxima and minima.

$a\ t = \log \frac{s_1}{s}$, is directly proportional to the time, and therefore the same for successive periods T. In particular the *natural* logarithm of the ratio of any maximum to the next succeeding is called the "*logarithmic decrement.*" It is the constant decrease in the logarithm of the amplitude which occurs during each whole

period $2\pi/r$, and may be written in the forms,

$$\lambda = \left| \begin{array}{l} \frac{1}{n} \log\left(\frac{s_1}{s_{n+1}}\right) \\ \log \frac{s_n}{s_{n+1}} = \log e^{a\,T} = a\,T = \frac{2\,a\pi}{r} = \frac{2\,a\pi}{\sqrt{b^2 - a^2}} \qquad (29) \\ \log s_n - \log s_{n+1} = \triangle \log s_n = \frac{\triangle s_n}{s_n} = \left(\frac{s_n - s_{n+1},}{s_n}\right. \end{array} \right.$$

for feeble damping)

The form $\Delta s_n/s_n$ is the fractional, or "percentage," damping in one complete oscillation.

Obviously the logarithmic decrement of the velocity "amplitude," as pictured in Figs. 5 and 6, could be treated in an analogous manner.

(e) *Ratio of Damped and Undamped Periods.*—By Table I the ratio of the periods of the damped and undamped harmonic oscillations is $T/T_o = b/\sqrt{b^2 - a^2} = 1 + \frac{1}{2}\ \frac{a^2}{b^2} + \ldots$, T_o being the undamped period. By (29) when a/b is small, $a/b = \lambda/2\pi$. Hence

$$T/T_o = 1 + \lambda^2/8\pi^2 = 1 + 0.01268\lambda^2 \qquad (30)$$

For example, if in one period the relative decrease of amplitude is, $\frac{s_n - s_n + 1}{s_n} = \lambda = 1/10$, the ratio of the damped and undamped periods is $T/T_o = 1.0001268$. This shows that when the damping is so great that successive maxima in the harmonic curve differ by 1/10, the period of the damped vibration is only about 1/8000 longer than the free period.

(f) *Coefficients in the Equation of Damped Harmonic Motion.*—If the time $n\ T$, of n successive oscillations, and the corresponding change of amplitude be observed, the values of a and b can be computed from the formulas already derived. Thus from $\lambda = a\ T$, and $T = 2\pi/\sqrt{b^2 - a^2}$, there follow

$$a = n\lambda/n\ T \qquad (31)$$

$$b = \sqrt{\lambda^2 + 4\pi^2}/T \qquad (32)$$

in which a is the slope and $n\lambda$, $n\ T$, the coördinates of the graph of the oscillation data plotted as in Fig. 6.

For a/b small, (32) gives $b \propto 1/T$, on recalling that $a/b = \lambda/2\pi$; and (31) taken with (30) gives $a \propto \lambda$. That is, for a moderately damped oscillation the elastic coefficient is a function chiefly of the observed period; the damping coefficient chiefly of the rate of decay. Both are still acceleration coefficients, as illustrated in Fig. 1. The corresponding frictional and elastic forces, as given in (1) and (2), are respectively $-2\,m\,a\,\dot{s}$, $-m\,b^2\,s$, m being the mass of the oscillating particle.

Case II: $a = b$; Critical Periodicity.—For the reason given in the mathematical preamble, the solution (19) and (20) fail when the roots of (3) are equal; but this on direct integration gives, if $\dot{s} = \dot{s}_o$, when $s = o = t$,

$$s = \dot{s}_o\, t\, e^{-at} \qquad (33)$$

$$\dot{s} = \dot{s}_o\, e^{-at}\,(1 - a\,t) \qquad (34)$$

These values of the displacement and speed are plotted as functions of the time in Fig. 7. Starting from zero, s increases till $\dot{s} = o$, $t = 1/a$, when it attains its maximum value $s_m = \dot{s}_o/ae = 0.368\ \dot{s}_o/a$; then diminishes asymptotically to zero in infinite time. Hence the period is infinite, and the motion is called "*aperiodic.*" The speed starting with the value $\dot{s}_o$, becomes zero when $t = 1/a$; becomes a minimum $\dot{s}_m = -\dot{s}_o/e^2 = -0.135\ \dot{s}_o$, in time $t = 2/a$; then dies out asymptotically to zero in infinite time. After its first reversal each of the graphs represents a subsidence, the one of displacement, the other of velocity. The sinusoids of Fig. 6 become straight lines in Fig. 7.

Case III: $a > b$; Aperiodic Motion.—The general values (19), (20), of the displacement and speed, when $a > b$, can, by use of (18), be reduced directly to

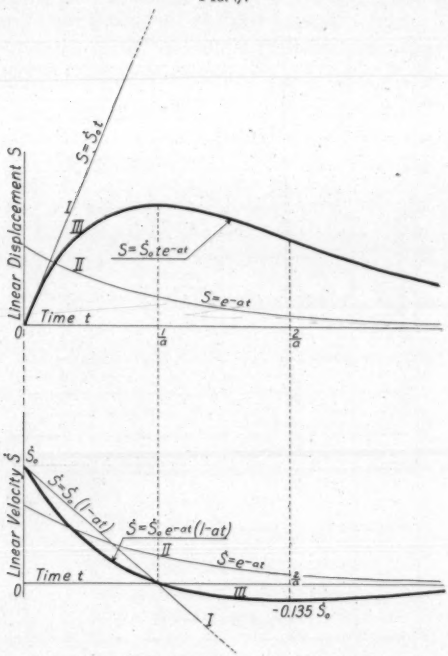
$$s = \frac{\dot{s}_o}{2\,r_1}\, e^{-at}\,(e^{r_1 t} - e^{-r_1 t}) \qquad (35)$$

$$s = \frac{\dot{s}_o}{2\,r_1}\, e^{-at}\left[\,(-a + r_1)\, e^{r_1 t} + (a + r_1)\, e^{-r_1 t}\,\right] \qquad (36)$$

The graphs of these equations simulate those of Fig. 7. Starting from zero, s increases till $\dot{s} = o$, $t = \frac{1}{2\,r_1} \log \frac{a + r_1}{a - r_1}$, when it attains its maximum value s_m, found by putting this value of t in (35); then diminishes asymptotically to zero in infinite time. The motion is therefore aperiodic. The speed, starting with the value

$\dot{s}_0$, falls to zero at the time t just found; changes sign and becomes a minimum when t equals twice this value; then dies out asymptotically in infinite time. After its first reversal each of the graphs for Case III, as for Case II, represents a subsidence. For $b = o$,

FIG. 7.



Displacement and speed in a periodic damped harmonic oscillation. I and II are components of III.

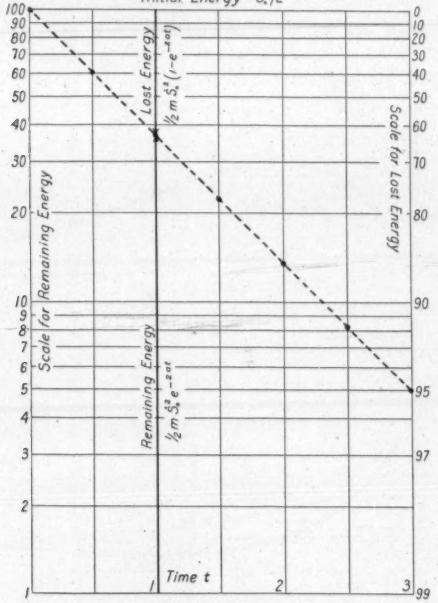
(35) and (36) are easily seen to become (7) and (8) respectively, since then $r_1 = \sqrt{a^2 - b^2} = a$.

Influence of a on Type of Motion.—The foregoing text shows that for $a = o$, the motion is sinusoidal; for $a < b$, it is oscillatory with decaying amplitude; for $a \geqq b$ it is aperiodic, *i.e.*, dies away without oscillation.

ENERGY OF DAMPED HARMONIC MOTION.

General Equation of Energy.—Except for a friction term, the energy expression for damped harmonic motion is like that for simple harmonic motion. If the particle m starts at $s = o = t$, with speed $\dot{s}_o$, its initial energy is $m\,\dot{s}_o^2/2$; at any later time its

FIG. 8.



Energy in periodic damped harmonic oscillation.

kinetic energy is $E = m\dot{s}^2/2$; its potential energy is $W = m\,b^2 s^2/2$, by (14); and their sum equals the initial energy less that consumed by the friction $f = -2m\,a\,\dot{s}$. Since the rate of frictional loss is $f\,\dot{s}\,d\,t = -2\,m\,a\,\dot{s}^2\,d\,t$, the total energy at any time t is

$$E + W = m\,\dot{s}_o^2/2 - 2\,m\,a \int_o^t \dot{s}^2 d\,t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37)$$

which has the form of (16) except for the last term.

Integral of Lost Energy.—The friction term can be integrated for any portion of the movement, since $\dot{s}$ has been found in terms of t, in earlier parts of the text. For any single stroke the lost energy can be found without integration, since at mid-stroke the total energy is $m\dot{s}^2/2$; and at the end of the stroke it is $m\ b\ s^2/2$; while s and $\dot{s}$ are given by (25) and (26).

For example, if the motion is periodic, the energy at mid-stroke and full stroke, respectively, is

$$E = \frac{1}{2}\ m\ \dot{s}^2 = \frac{1}{2}\ m\ \dot{s}_0{}^2 e^{-2at},\ W = \frac{1}{2}\ m\ b^2 s^2 = \frac{1}{2}\ m\ \dot{s}_0{}^2 e^{-2at}$$

and these values plotted against time, on semilogarithmic paper, lie on a straight line, as in Fig. 8. For the particular values of a/b that make $\cos \epsilon = 1$ in (25), the graph in Fig. 8 delineates at every point the value of the integral in (37); but otherwise only at the marked points, for which the energy is all kinetic or all potential.

INFLUENCE OF MASS IN DAMPED HARMONIC MOTION.

Kinematic Equation Containing Mass Explicitly.—The general equation (3) contains implicitly the mass m, of the particle, and may be rewritten in the form

$$\ddot{s} + \frac{2a_1}{m}\ \dot{s} + \frac{b_1{}^2}{m}\ s = o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

in which all the terms are still accelerations. The following definitions may be useful:

$\frac{2a_1}{m} \equiv$ coefficient of damping acceleration,

$\frac{2a_1\dot{s}}{m} \equiv$ damping acceleration,

$2a_1 \equiv$ coefficient of damping force,

$2a_1\dot{s} \equiv$ damping force.

Kinematic Effect of Mass.—The effect of m in modulating the motion can now be seen by placing these two coefficients, respectively, in place of $2a$ and b^2 in the previous equations of the text. Thus, if they be substituted in Table I, they show that increase of m prolongs the periods $2\pi/b$, $2\pi b/\sqrt{b^2 - a^2}$, respectively, of undamped and damped motions. Similarly m is seen to diminish the rate of damping $e^{\frac{-a_1 t}{m}}$, and the rate of dissipation of energy $2\ m\ \frac{a_1}{m}\ \dot{s}^2$ where $\dot{s} \propto e^{-\frac{a_1}{m} t}$, as seen by (22).

APPLICATION TO ANGULAR MOTION.

Equation of Angular Damped Harmonic Motion.—All the foregoing equations can be directly applied to the vibrations of a body about a fixed axis, usually taken as the principal centroidal axis, if m be replaced by I, the moment of inertia of the body for that axis, and if s, $\dot{s}$, $\ddot{s}$ be replaced by the corresponding angular values. Thus the angular analogue of (38) may be written

$$\ddot{\theta} + \frac{2\mu_1}{I}\dot{\theta} + \frac{K_1^2}{I}\theta = o \quad \ldots\ldots (39)$$

and the coefficients of $\dot{\theta}$ and θ may be respectively substituted for $2a$ and b^2 in the equations (1) to (37), to derive the corresponding expressions for angular vibration. For example, the period $T = 2\pi/b$, for undamped motion, becomes

$$T = 2\pi\sqrt{I}/K_1 \quad \ldots\ldots (40)$$

while a similar expression is found for damped motion.

Formula for Moment of Inertia in Torsional Vibration.—Equation (40) is sometimes used to determine I for a model. If T is observed in a vibration test, and the elastic coefficient K_1 is known from a torsion test, I can be computed directly from (40). It may be recalled that in such torsion test the torsional moment M, and the ensuing displacement θ, in radians, are measured to determine $K_1 = M/\theta$.

If K_1 is not supplied, T_1 may be observed in a second vibration test with the same model having an added moment of inertia I_1, and will evidently satisfy the formula $T^1 = 2\pi\sqrt{I + I_1}/K_1$. From this and (40) one derives

$$I = I_1 \frac{T^2}{T_1^2 - T^2} \quad \ldots\ldots (41)$$

which can be used to find I from two vibration tests, when the elasticity of the spring is unknown.

A similar operation may be used to determine I when the motion is damped.

PART III. FORCED OSCILLATIONS.

KINEMATICS OF RECTILINEAR FORCED OSCILLATIONS.

The foregoing text treats briefly the theory of the free rectilinear oscillation of a particle both undamped and damped, and indicates a like treatment for the theory of oscillation of a rigid

body about a fixed axis. In closing, attention may be given also to a simple case of a forced oscillation superposed upon the free.

Equation of Forced Oscillation and Resultant Oscillation.—When a particle is performing free vibrations as represented by (3), let it be subjected to a single additional acceleration from without, parallel to the given motion, and a continuous function of the time. This latter may have any one of numerous forms. For the present let the applied acceleration be taken as a simple harmonic function of the time; so that (3) becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = h \sin \omega t \quad \ldots\ldots (42)$$

The complete solution of this equation can be written as the sum of its complementary function (19), and its particular integral, which is easily shown to have the form

$$s = \frac{h}{\sqrt{(b^2 - \omega^2)^2 + 4\epsilon^2\omega^2}} \sin(\omega t - \varepsilon) \quad \ldots\ldots (43)$$

$$= \frac{h \sin \varepsilon}{2a\omega} \sin(\omega t - \varepsilon) \quad \ldots\ldots (43')$$

where

$$\tan \varepsilon = 2a\omega/(b^2 - \omega^2) \quad \ldots\ldots (44)$$

And if the complementary function has the particular form (21), for a periodic oscillation, the complete integral is

$$s = \frac{\dot{s}_o}{r} e^{-at} \sin rt + \frac{h}{\sqrt{(b^2 - \omega^2)^2 + 4a^2\omega^2}} \sin(\omega t - \varepsilon) \quad \ldots\ldots (45)$$

where the last term represents the forced oscillation, which is superposed upon the free one given by the other term; and ϵ is the phase difference between the applied acceleration and the consequent oscillation.

Magnitude of the Resultant Oscillation.—Since the right member of (45) has only t variable, its first term, if $a \neq o$, is graphically represented by a damped, its second term by an undamped, sine curve; and hence their resultant gradually becomes an undamped sine curve represented by the second term. That is, the free vibration gradually dies out, and the oscillation of the particle has for steady motion that due to the applied acceleration only. But in the ideal case when $a = o$, the motion is the resultant of a permanent free simple harmonic oscillation added to a forced oscillation, also assumed permanent, whose peculiarities are still

to be examined. In general the periods $2\pi/r$ and $2\pi/\omega$, of the two motions, and their frequencies $r/2\pi$, $\omega/2\pi$, are different.

Period and Magnitude of the Forced Oscillation.—The forced oscillation (43) has the same period $2\pi/\omega$ as the applied acceleration, and contains four arbitrary parameters, h, a, b, ω, in the expression for its amplitude. This latter varies directly as h, the coefficient of intensity of the applied acceleration, and inversely as $(b^2-\omega^2)^2+4\ a^2\omega^2$, which has three arbitrary parameters. For a given value of h, therefore, the amplitude will be small when this binomial is large, and *vice versa*.

Conditions Making Forced Oscillation Small.—The condition that, for a given intensity h, the forced vibration shall be feeble is that $(b^1-\omega^2)^2+4\ a^2\omega^2$ be large, where a, b and ω are positive. This can occur when $b-\omega$ is large; that is, when there is a large difference between the frequencies of the undamped free oscillation and the applied acceleration; also when a ω is large, which may be due to large damping or to high frequency.

Conditions Making Forced Oscillation Large.—The general condition that the forced oscillation shall be large is that $(b^2-\omega^2)^2+4\ a^2\omega^2$ be small, which means that both $b-\omega$ and $a\omega$ are small. As $b-\omega$ tends toward zero $\tan\epsilon, = 2a\omega/(b^2-\omega^2)$, tends toward $\pm\infty$, that is ϵ approaches $\pi/2$ from either side, according as b is greater or less than ω. The condition $a\omega$ small indicates that, even with considerable damping, the oscillation can be large if the frequency, $\omega/2\pi$, of the applied acceleration is sufficiently small, while nearly equalling the frequency, b/π, of the undamped free oscillation.

For $a=o$, if $b-\omega\neq o$, $\tan\epsilon=o$, and the forced oscillation (43) becomes $s=\dfrac{h}{b^2-\omega^2}\sin\omega t$, showing that the phases of the motion and of the applied acceleration agree in sign if $b>\omega$, and *vice versa*. But if $b-\omega=o$, $\tan\epsilon=o/o$, and the integral of (42) for this special case can better be written

$$s=\frac{-ht}{2\omega}\cos\omega t \qquad (46)$$

which indicates a divergent harmonic motion whose period is that of the undamped free oscillation, and whose amplitude $h\ t/2\ \omega$ increases directly as the time, having infinity as its "steady" value. For large values of t the speed of the particle, $\dot{s}=\dfrac{ht}{2}\sin\omega t$,

has the same phase as the applied acceleration $h \sin \omega t$. This case is treated somewhat differently by Lord Rayleigh, in his "Theory of Sound," § 41, which is recommended for present reference, and from which is taken the expression (51) below.

Special Forms of the General Equation.—The general equation (42) may be given various interesting special forms by assigning certain particular values to the constant coefficients, a, b, h, ω. Thus if a alone is zero the equation is that of a forced undamped harmonic oscillation $\ddot{s} - b^2 s = h \sin \omega t$, an interesting case of which is given in (46). Again, if in (42) $h \sin \omega t$ is constant, the equation is that of a damped harmonic oscillation with a constant disturbing force. In this case, which is of some interest in aeronautic experiments, (42) becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (47)$$

whose solution is

$$s = s_1 + c/b^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (48)$$

where s_1 is the solution of (3).

It may be recalled that, for a free damped periodic motion, the plot of s_{max} on semilogarithmic paper is a dotted straight line, as in Fig. 6. The form of (48) shows that the graph ceases to be straight when a constant disturbing acceleration occurs.

More General Forced Oscillation.—By Fourier's theorem any single-valued periodic function $f(t)$, of period $T = 2\pi/\omega$, can be expanded, between definite limits of the variable, in a series of the form

$$f(t) = h_0 + h_1 \sin(\omega t + \varepsilon_1) + h_2 \sin(\omega \cdot 2t + \varepsilon_2) + h_3 \sin(\omega \cdot 3t + \varepsilon_3) + \ldots\ldots\ldots\ldots\ldots\ldots (49)$$

Hence if an applied acceleration of this form be substituted for the second member of (42), the equation of the forced oscillation of the particle becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = \sum_0^n h_n \sin(\omega \cdot nt + \varepsilon_n) \ldots\ldots\ldots\ldots\ldots\ldots (50)$$

The integral of this takes the form of (45), but with its last term summational. Thus the rectilinear motion of the particle consists of a damped free oscillation, of period $2\pi/r$, upon which is superposed a complex harmonic motion composed of n forced oscillations of periods T, $T/2$, $T/3$, . . . T/n, and phases ϵ_1, ϵ_2, . . . ϵ_n.

ENERGY OF FORCED OSCILLATIONS.

The kinetic energy of the forced oscillation, whether damped or undamped, is proportional to $\dot{s}^2$. For the damped one (43′) gives, if the speed is $\dot{s}_0$, when $s = o$,

$$\text{Energy} \propto \dot{s}_0^2 \propto \sin^2 \epsilon \quad \ldots\ldots\ldots\

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTES ON SMALL-FLOW METERS FOR AIR, ESPECIALLY ORIFICE METERS.[1]

By Edgar Buckingham.

[ABSTRACT.]

FOR small-orifice meters the thickness of the orifice plate should be from one to two times the diameter of the orifice, and the entrance should be smooth and well rounded, *i.e.*, trumpet shaped.

The "theoretical" discharge rate of dry air through such an orifice of diameter D mm. is

$$V \text{ (litres/min)} = 2.12\, BD^2\sqrt{T°C} \qquad (1)$$

where V = the volume measured at the initial pressure and temperature,

T = the absolute temperature before the orifice

$$B = \sqrt{r^{10/7} - r^{12/7}} \qquad (2)$$

and

$r = \rho_1/\rho$ = the ratio of the back to the initial pressure. If V_0 is this same volume reduced to the ice point and 1 atmosphere, we have

$$V_0 \text{(litres/min)} = 0.761\, BD^2\frac{p}{\sqrt{T°C}} \qquad (3)$$

where ρ = the initial absolute pressure in mm. of mercury.

Actual discharge rates are a few per cent. smaller than theoretical. The discharge coefficient (actual/theoretical) cannot be predicted accurately for small orifices, and experimental standardization is necessary; but the formulas give approximate results (a little too high) and may be used for selecting or designing an orifice to give a certain discharge under a certain suction head.

If the initial pressure is one standard atmosphere and the air is drawn through by a suction head of h cm. of water, the pressure ratio r to be used in equation (2) is $r = (1034 - h)/1034$. Under these circumstances we have the value of B shown in the following table. The values of V are computed from (1) for a 1-mm. hole,

* Communicated by the Director.

[1] Technologic Paper No. 183.

an initial temperature at 18° C., and an initial pressure of 760 mm. Hg.

h	r	B	V
80	0.9226	0.1424	5.144
60	.9421	.1247	4.505
40	.9613	.1029	3.719
30	.9710	.0896	3.238
20	.9807	.0736	2.658
15	.9855	.0639	2.313
10	.9903	.0523	1.889
7	.9932	.0438	1.583
4	.9961	.0332	1.199
2	.9981	.0235	0.848
1	.9990	.0166	.600
0.5	.9995	.0118	.424

Moist air will act nearly like dry unless condensation occurs in the walls of the orifice. When this occurs with small orifices the discharge rate is irregular, and the air should be dried or the orifice warmed.

The diameter of the pipe in which the orifice plate forms a diaphragm should be at least four times the diameter of the orifice, so as to eliminate the effect of the "speed of approach."

Sharp-edged orifices may be used, but they need more complete standardization, because the discharge coefficient varies with the value of r.

Capillary tubes may be used to furnish the required resistance to flow, but they are likely to clog. For accurate work they must also be water jacketed if used below the critical speed, because of the change of viscosity of air with temperature. If such a tube is standardized below its critical speed, the standardization must not be used for speeds above the critical, and *vice versa*.

THE PRESENT STATUS OF THE CONSTANTS AND VERIFICATION OF THE LAWS OF THERMAL RADIATION OF A UNIFORMLY HEATED ENCLOSURE.[2]

By W. W. Coblentz.

[ABSTRACT.]

AN examination is made of the instruments, methods, and experimental data pertaining to various determinations of the constant, σ, of total radiation and the constant, c, of spectral radiation

[2] Scientific Paper No. 406.

of a black body. After making obvious corrections for reflection from the receiver and for atmospheric absorption, the determinations of various experimenters are in close agreement, giving a value of $\sigma = 5.72 \times 10^{-5}$ ergs, and $c = 14320$ micron degrees.

GYPSUM—PROPERTIES, DEFINITIONS AND USES.[1]

[ABSTRACT.]

OWING to the rapid growth of the gypsum industry, the nomenclature has not been standardized. A brief description of the various gypsum products will tend to fix their names.

Gypsum is a soft white rock, usually occurring in beds. Other varieties of the same material are known as gypsite and alabaster. It is of common occurrence throughout the United States. Chemically it is a calcium sulphate combined with water. Anhydrite is a variety which contains no water.

Raw gypsum is used for the manufacture of Portland cement and as a fertilizer.

Calcined gypsum is made by heating raw gypsum in a kettle until the first evolution of water has ceased. It contains one-fourth as much water as the raw material. This product is frequently known as plaster of Paris and is used either as such or as the basic ingredient for the manufacture of wall plaster, potters' plaster, dental plaster, etc. Large quantities of it are used in the manufacture of Portland cement, plate glass, and cold-water paints.

When calcined gypsum is mixed with water, it sets to form a hard mass. The time required for this reaction can be varied at will by the addition of suitable retarders or accelerators.

Neat gypsum plaster is calcined gypsum to which has been added some material (such as hydrated lime) to improve its working quality, and the proper amount of retarder. Gypsum sanded plasters are mixed with sand ready for use. Any of these plasters may or may not be "fibred" with either hair or wood fibre. And a special wood-fibred gypsum plaster is made to be used without sand.

Gypsum plasters have excellent fire-resistive ability.

The raw gypsum can be heated until all of the water is given off. The product so formed sets more quickly than calcined gypsum. It is not marketed, but is used at the factory to make such

[1] Circular No. 108.

products as gypsum tile, gypsum plaster board, gypsum wall board, etc.

Further heating of the raw gypsum forms a material which sets very slowly. An accelerated variety of this is marketed as Keene's cement.

Gypsum tiles are factory-made building blocks. They come in a great variety of sizes, either plain or reinforced. They are used for building walls and roofs.

Gypsum plaster board consists usually of a sheet of set gypsum plaster between two sheets of unsized paper. It comes in many sizes, usually about 3 feet square by ⅜ inch thick. It is used instead of lath as a backing for plaster.

Gypsum wall board is of about the same construction as gypsum plaster board, but the paper is sized so as to furnish the finished surface of the wall. It comes in strips of 4 feet wide by any length from 6 to 14 feet, by ⅝ inch thick.

The Bureau is coöperating with the Gypsum Industries Association in research work on this subject, and the Association has established a fellowship at the Bureau.

Recommended specifications for calcined gypsum, neat gypsum plaster, gypsum plaster board, and gypsum wall board are given in full, for which the original paper should be consulted.

EFFECT OF THE RATE OF COOLING ON THE MAGNETIC AND OTHER PROPERTIES OF AN ANNEALED EUTECTOID CARBON STEEL.[4]

By C. Nusbaum and W. L. Cheney.

[ABSTRACT.]

Six specimens of eutectoid carbon steel were selected, heated to 800° C., and allowed to cool at various rates. One was cooled in air, another in lime, and the others in the furnace at slower and slower rates. Observations were then made to determine the magnetic and other properties. Normal induction measurements at ordinary magnetizing forces were made with the Burrows permeameter and at high field values with a modified form of "isthmus method." Resistance measurements were made by a comparison method; the "fall of potential," both across the terminals of a standard shunt connected in series with the current-carrying specimen and across knife-edge terminals in

[4] Scientific Paper No. 408.

contact with the specimen, was measured by a Wolff potentiometer. Hardness measurements were made by means of a self-recording Shore scleroscope. Micrographs were made at a magnification of 500 diameters, representing the average structural condition shown by etching for 10 seconds in 5 per cent. alcoholic picric acid. There is found a marked difference in structure among the furnace-cooled, the air-cooled, and the lime-cooled specimens.

A table is given showing the time each specimen was held at 800° C., the nature of the cooling, the time of cooling from 800° C. to 650° C., the maximum permeability, the induction for particular values of the magnetizing force, the residual induction, the coercive force, the maximum intensity of magnetization, the hardness, and the resistivity. Figures are also included which show the normal induction, the permeability, and the reciprocal of the susceptibility plotted against the magnetizing force, as well as the time-temperature curves.

The experimental results show:

1. With a decrease in the cooling rate there is a marked increase in the value of the maximum induction for a given value of the magnetizing force, an increase in the maximum permeability, and a decrease in the coercive force.

2. As the structure is changed from an essentially sorbitic one to "divorced" pearlite, there is a gradual shifting toward the origin of the break in the reductivity line and an increase in the difference between the "real" and "apparent" values of the maximum intensity of magnetization.

3. There is a good agreement between the values of the coercive force and the scleroscope hardness as influenced by the various cooling rates.

A SIMPLE PORTABLE INSTRUMENT FOR THE ABSOLUTE MEASUREMENT OF REFLECTION AND TRANSMISSION FACTORS.[5]

By A. H. Taylor.

[ABSTRACT.]

A NEW type of absolute reflectometer was recently described in Scientific Paper No. 391 of the Bureau of Standards. The operation of that instrument is somewhat complicated, and a much

[5] Scientific Paper No. 405.

simpler one has now been devised. This new instrument, like the one previously described, is based on the principle of the integrating sphere, but is operated in an entirely different manner.

The reflectometer is a sphere with a small segment cut away, leaving a hole over which the surface to be tested is placed. The wall of the sphere is viewed through a small hole by means of a portable photometer, the spot viewed being screened from the test surface. A lighting tube, set at an angle to the sphere surface, is arranged to rotate about an axis normal to the surface of the sphere, so that the direct light can be thrown on the test surface or on the sphere wall. The theory of the integrating sphere shows that the reflection factor of the test surface is simply the ratio of the photometer readings in the two cases, no assumption being made as to the way in which the light is reflected from the test surface. Moreover, the reflection factor measured is not affected by selective reflection by the sphere walls.

No accurate voltage adjustment of the lamps in the photometer and the reflectometer is necessary, as both operate from the same battery. The use of a low-voltage flashlight lamp in the lighting tube makes the instrument very portable and convenient. An absolute instrument of this type is much better than an instrument giving relative values because no standard surface is required and it is not necessary for lamps or sphere surface to remain constant from day to day. By the addition of an exterior light source the same instrument can be used to measure transmission factors of clear or diffusing media.

NATIONAL SAFETY CODE FOR THE PROTECTION OF THE HEADS AND EYES OF INDUSTRIAL WORKERS.[6]

[ABSTRACT.]

IN 1918 the Bureau of Standards coöperated with the safety engineers of the War and Navy Departments in the preparation of a set of safety standards to be applied in the government establishments. Among these standards was one for head and eye protection, and this formed the basis for the National Safety Code for the Protection of the Heads and Eyes of Industrial Workers. These rules were further developed through study and experimental work at the Bureau, and conferences with other individuals who have had experience in eye protection.

[6] Handbook of the Bureau No. 2.

Preliminary drafts were issued in December, 1918, and in May, September and December, 1919, and in March and August, 1920, further revisions were made. In this work the Bureau wishes to acknowledge the assistance rendered by the Advisory Committee. The rules are designed to give mechanical and optical protection to the eyes and heads of workers in certain occupations which involve such hazards.

No attempt has been made to specify a particular style and strength of goggle for a particular operation, but rather an attempt has been made to classify the character of the hazards which are existent in industry, leaving it to the employer, or the administrative authority or other responsible party, to assign the particular operation concerned to its proper group.

The various operations and processes which require protection to the head and eyes have been classified into nine groups according to the degree of hazard, or because the peculiar nature of the hazard makes it necessary to provide a protector having distinctive features.

The hazards from flying solid particles ordinarily encountered are separated into three groups designated A, B, and C. The first group will contain all operations wherein the mechanical hazard is so great as to warrant the selection of protectors the parts of which have passed mechanical tests assuring adequate strength. In class B are grouped all operations in which the protector must prevent the entrance of small flying particles into the eye. The lens will not be subjected to severe blows and hence no mechanical tests are necessary. While strength of the frames of goggles used for this purpose is not a prime requisite, definite requirements for the material entering into their construction is necessary. Hence a separate group for these processes has been made. In class C, occupations similar to auto driving, protectors are used merely to keep small foreign particles out of the eyes, and hence the protector need not withstand any special strength tests.

In processes where splashing metal is used the special hazard is from burns from molten metal which might be projected with force. The degree of hazard varies with the operations, and therefore a number of different methods of protection are suitable. Workers handling fumes, gases, and liquids require protectors of various designs, each one having protective qualities peculiarly fitted for the work. These operations have accordingly also been classed in a separate group.

The hazards incident to sand-blasting are not met in any other process. Hence this subject is treated separately.

In the last three groups are classified all of the operations where the worker is exposed to harmful radiant energy. Definite limits to the transmission of the radiant energy through the lens or window of the protector have been set. These limits are based on the degree of hazard involved, an analysis of which results in the division of hazards into three groups. The Bureau will be glad to receive criticisms of the provisions and recommendations for improvement of the Code, especially such as are based upon actual experience in the application of the rules. After a period of trial and experience it is expected to issue a new edition with such changes and corrections as that experience may dictate.

The rules are accompanied by a discussion intended to assist in their interpretation and application and to show the reasons for including some of them in the text.

REPORT OF THE THIRTEENTH ANNUAL CONFERENCE ON WEIGHTS AND MEASUURES.[1]

[ABSTRACT.]

THE Annual Conference on Weights and Measures of the United States is an organization composed of State and local weights and measures officials from all parts of the country, which meets yearly at the Bureau of Standards, Washington, D. C. These Conferences are also largely attended by representatives of manufacturers of weighing and measuring devices and by other guests interested in the general subject of weights and measures. The Conference is vitally concerned with the improvement and efficient enforcement of Federal, State, and local weights and measures laws and with the improvement of rules and regulations, specifications and tolerances, and methods of inspection. It also considers means to bring about a greater measure of uniformity throughout the country in these matters.

This publication is a verbatim report of the proceedings of the thirteenth annual meeting. It contains addresses by the Secretary of Commerce and by the president of the Conference; reports of delegates representing various States as to conditions in their jurisdictions; papers on the subjects of gasoline pumps from the standpoint of safety, net weight, the weight standardization of

[1] Miscellaneous Publication No. 43.

bread, the standardization of containers for foodstuffs, weights and measures education in the schools, and machine measurements for dry-goods; and the resolutions adopted by the Conference. The report of the committee on specifications and tolerances which was devoted to the subject of liquid-measuring devices is given, as well as the discussion concerning the various provisions. The appendix consists of the complete specifications and tolerances adopted for this class of apparatus.

EFFECT OF REPEATED REVERSALS OF STRESSES ON DOUBLE REINFORCED CONCRETE BEAMS.[8]

By W. A. Slater, G. A. Smith and H. P. Mueller.

[ABSTRACT.]

THE tests reported in this paper were made as a part of the investigations carried out in the concrete-ship program of the Emergency Fleet Corporation. The purpose was to stimulate to some extent the effect produced upon a ship by the action of the waves which causes an alternate upward and downward deflection of the ship. This is the action known in ship-building terms as "hogging" and "sagging."

The specimens used for the test were concrete beams which had reinforcement both in the top and in the bottom. The beams were 4 by 6 inches in cross section over all and were tested with a span of 8 feet. The load was applied at points 12 inches apart, each point being 6 inches from the centre of the span. It was applied at the rate of about seventeen cycles per minute (one cycle includes one application of load upward and one application of load downward). The load was applied as dead weight by means of levers so designed that ten times as much load came upon the beam as was applied to the lever. The levers were operated by means of an electric motor acting through a walking beam.

Four beams were tested to failure and a fifth was loaded alternately through two million cycles when the test was discontinued. At the time of discontinuation of the test the beam did not appear to be approaching failure.

For all of the beams tested to failure, failure was by tension in the steel. Generally the beams in which the highest stresses were developed in the test withstood a smaller number of repetitions of load than those in which the measured stresses were

[8] Technologic Paper No. 182.

smaller. However, even the largest number of repetitions was so small that failure in the steel would not have been expected at the time at which it did occur considering that the observed stresses were very low. Other factors than the intensity of the tensile and compressive stresses seem to have had a part in bringing about the early tension failure.

All of the tension failures in the reinforcing bars occurred at sections where large cracks extended entirely across the section of the beam. It is possible that in some cases the bending at these cracks was sufficient to make the bending of the bar an important factor in causing failure. The slipping of bars at the ends, such as happened in one of the beams, would permit the opening of wide cracks and accentuate this tendency.

The presence of the gage holes in the bars seems to have had some influence in hastening tension failure, but this influence was not very distinct.

The quality of steel used for most of the reinforcement was poor and this would contribute to bringing about early failure. However, this alone would not account for the small number of repetitions of stress generally required in these tests to produce failure.

After 7000 cycles of load the slip at the end of the bar in one of the beams was less than 0.001 in.; that is to say, less than the amount which has been taken as the criterion of safe conditions based on tests of the bond resistance between concrete and steel. Yet, after 400,000 cycles of load, the amount of slip had increased so much that failure by slipping of the bars seemed imminent. It seems that the intervention of tension failure at an unexpectedly small number of repetitions of load prevented the bond failure of this specimen.

PHYSICAL PROPERTIES OF MATERIALS: COMPILED TABLES. I. STRENGTHS AND RELATED PROPERTIES OF METALS AND CERTAIN OTHER ENGINEERING MATERIALS.[9]

[ABSTRACT.]

THIS circular aims to present, in readily accessible form, the best available data on the strengths and related properties of metals, alloys, and certain non-ferrous metals. Among the mate-

[9] Circular No. 101.

rials treated are iron, carbon steels, alloy steels; wire and wire rope; semi-steel; aluminum, copper, and miscellaneous metals and their alloys; rope, rubber, leather, and woods.

The tensile strength, proportional limit, percentage elongation in two inches, percentage reduction of area, Brinell and scleroscope hardness corresponding to a certain composition, density and method of preparation are shown in most cases for the metals and alloys.

In addition, figures are shown in many instances for the compressive and shearing strengths, modulus of rupture and Erichsen value.

The circular also includes definitions of the properties treated and references to sources.

EXPERIMENTS ON COPPER CRUSHER CYLINDERS.[10]

By Alexander I. Krynitsky.

[ABSTRACT.]

THE metallic cylinders, usually made of exceedingly pure copper or lead, employed for the measurement of pressure developed by the products of decomposition of powder in the testing of powder and ammunition, are known as crusher cylinders.

On firing, the pressure of the gases shortens the cylinder longitudinally by means of the piston of the special apparatus used. The amount of this compression, in conjunction with the proper value taken from a previously prepared table of values showing the relation between the compressions and corresponding total sets of the length of each lot of cylinders, serves to determine the maximum pressure of the products of decomposition. These copper cylinders are the subject of this investigation, which was carried out in 1919 by the Bureau of Standards in connection with the standardization of the crusher gage method for pressure testing of small arms, ammunition, and powder, and which consisted of a series of compressions of the annealed copper cylinders, one set having a mean length of 0.4000 in. and the others 0.5000 in., with a mean diameter of 0.2260 in. in the former and 0.2500 in. in the later ones, on a standard 10,000-lb. Riehlé testing machine. From the results of these investigations it appears that:

1. The length of copper crushed cylinders decreases consider-

[10] Technologic Paper No. 185.

ably under repeated application of the same load. The relation between this decrease in length and number of times load was applied is within certain limits nearly proportional.

2. The change in length with repeated constant loads is greater with the greater load.

3. Repeated application of successive decreasing loads within certain limits causes a gradual decrease in length.

4. The length changes but slightly with longer application of load when the load is applied in such a manner as to produce the maximum stress only for an instant.

5. Application of the same load for the same period (greater than about 3 seconds), but holding the beam balanced by means of one additional application (impulse) of the same load after the beam had started to drop, causes about twice the decrease in length observed in the previous case, when the beam was allowed to drop after balance was obtained.

6. Double applications of the same load for 2½ seconds each time, the second load being applied at some interval after the first load has been released, causes a decrease in length much greater than in the previous two cases. This holds true even when the pressure is applied for as long as 25 seconds in the case of paragraphs 4 and 5.

7. In case the last load is considerably greater than any previous loads, the change in length due to last load is practically independent of the previous loads, *i.e.*, it is the same as would be obtained by compressing a previously uncompressed cylinder.

8. When two successive loads of considerable amount (approximately 40,000 lbs. per sq. in.) are applied, the second being greater than the first, the change in length due to the last load is considerably greater than that obtained where the pressure is applied on previously uncompressed cylinders, and this difference increases as the difference between the two loads successively applied decreases.

9. When several successive loads of considerable amount are applied, differing by about 2000 lbs. per sq. in., each greater than the preceding load, the total change in length of the cylinders following the last compression increases with the number of loads previously applied.

10. It appears probable that aging at temperatures within 0–100° C. softens the compressed copper somewhat.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

REFLECTION CHARACTERISTICS OF PROJECTION SCREENS.[1]

By L. A. Jones and M. F. Fillius.

THE importance of using a surface of proper reflection characteristics in the projection of motion pictures is emphasized. A gonio photometer constructed especially for the measurement of the reflection characteristics of surfaces is described and its use explained. The results of measurements on some thirty-six different surfaces consisting largely of commercial motion-picture screens are given. These screens are shown to fall into three general classes, according to the completeness with which the reflected light is diffused. In Class A are included those screens which reflect a large proportion of the incident light within a very narrow angle, while in Class C are those screens which give almost complete diffusion. Class B includes the screens which are intermediate between the extremes represented by classes A and C. A graphic representation of the distribution of reflected light is given for each of the screens examined. On the assumption that the brightness of a screen as viewed on the axis should not be greater than four times the brightness when observed at the maximum angle, a method of choosing a screen for any particular condition was outlined and the constants of the various screens necessary for the making of such a choice are computed and tabulated.

* Communicated by the Director.

[1] Trans. Soc. Mot. Pict. Eng., No. 11, p. 59. Communication No. 114, from the Research Laboratory of the Eastman Kodak Company.

Heating by Catalysis. (*La Nature*, December 25, 1920.)—Early in the nineteenth century Humphry Davy discovered that a spiral of platinum, previously heated, will remain incandescent when immersed in a mixure of air and inflammable gas. While the platinum remains unchanged the gas is decomposed. From this simple beginning have grown the many catalytic processes now known. The manufacture of sulphuric acid by the contact process is an example of the practical application of catalysis.

In the winter of 1914–1915 the French aviation service experienced vexation from the delay in starting the motors, due to the too low temperature of the water or of the radiators. Loss of time in setting out brought in its train failure to attain the purpose of the flight. This difficulty was overcome by Messrs. L. Lumière and J. Herck, who devised a catalytic heater that kept the radiator warm and at the same time avoided any danger of setting on fire the very inflammable avion.

In the bottom of a metal cylinder is a spongy body, such as sheet cotton, soaked with gasoline. From this a wick extends upward and terminates a short distance below a plug of asbestos impregnated with platinum. At the beginning this platinized plug is heated, then as the gasoline vapor continues to come in contact with it, chemical change by catalysis is brought about so that a temperature of about 250° C. is maintained without a flame. A company is now making heating apparatus of this kind, designated as "Thermix," ranging in size from such as will heat the pocket or a muff to those designed to temper the coolness of a room. For 60 cu. m. an hourly consumption of 120 grams of gasoline is the rating.

G. F. S.

Crisis in the American Potash Industry. (*A. C. S. News Service*, C-250-2, 1-25-21.)—Dr. John E. Teeple recently presented before the Rochester section of the A. C. S. some statements as to the falling off in the manufacture of potash fertilizers in this country.

In 1918, the banner year, 128 different plants operated, giving a total production of over 54,000 tons of potassium oxide. In 1919, with the fall of the price of potash, this production dropped to about 30,000 tons. Out of the 128 plants reported as producing in 1918, only 43 were reported as producing in 1920. With the price of potash in 1921 still lower than it was in 1920, we may expect a still greater falling off in the number of producing plants, and possibly in the total output.

Up to the present time probably 70 per cent. of the total production of potash in this country came from the natural brines found in certain lakes in Nebraska, Utah, and California. The largest producer in the United States is a plant working on Searles Lake in California.

NOTES FROM THE U. S. BUREAU OF MINES.*

QUALITY OF GASOLINE MARKETED IN THE UNITED STATES.

By H. H. Hill and E. W. Dean.

In the spring of 1919 a comprehensive survey of motor gasolines sold in the United States was made by the Bureau of Mines. The data obtained in this survey were used by the Committee on Standardization of Petroleum Specifications for setting a new specification for Federal purchases of motor gasoline. The complete report of this investigation with detailed tables of analyses has recently been issued as Bulletin 191 of the bureau.

INVESTIGATION OF COLORADO LOW-GRADE ORES.

By R. R. Hornor and W. H. Coghill.

The investigation of low-grade and complex ores in Colorado, conducted jointly by the U. S. Bureau of Mines and the Colorado School of Mines under a fund appropriated by the State legislature, has been completed. The object of the investigation was to determine the character and extent of the low-grade ores in the State and, where found in sufficient quantity, to conduct concentration tests in an effort to devise a cheap and suitable treatment. The results are being published as Bulletin 10 of the Colorado Bureau of Mines.

CHLORINATION OF NATURAL GAS.

By G. W. Jones.

The Bureau of Mines has conducted, in its natural-gas laboratories at Pittsburgh, an investigation of the making of useful products by the chlorination of natural gas. Many gas fields yield natural gas which is free from the higher paraffins and is especially suitable for making chlorinated products. In those fields which are too remote from industrial centres to warrant

* Communicated by the Director.

expense of piping, utilization of the gas for the manufacture of chlorinated products seems desirable, if such manufacture can be placed on a feasible and profitable basis. Since "wet" gases are being utilized for obtaining gasoline, whereas "dry" gases are of no value for gasoline production but offer possibilities for chlorination, only the "dry" gases were studied.

The studies were confined to the effect of catalyzers on the chlorinating reaction, also the effect of temperature, and to a smaller extent, that of water vapor. Details of the experiments and the results obtained are given in Technical Paper 255, "Chlorination of Natural Gas," by G. W. Jones, V. C. Allison and M. H. Meighan.

TESTS OF CARBON MONOXIDE DETECTOR IN MINES.

By D. Harrington.

ONE of the products of the U. S. Chemical Warfare Service is a simple, portable instrument for quick determination of small quantities of carbon monoxide in air. The device has been diverted to commercial uses for determination of small but possibly dangerous quantities of CO in garages, sewers, etc. Recent tests by the Bureau of Mines indicate that it probably has a definite field of use in testing mine air in connection with fires and explosions and in confined places, suspected to contain small amounts of CO.

PROPERTIES OF CRUDE OILS FROM EASTERN FIELDS IN UNITED STATES.

By E. W. Dean.

THE Bureau of Mines is making a comprehensive study of the properties of crude oils from the various producing fields in this country. Typical samples are collected and analyzed for specific gravity, sulphur content, water content, distillation products, and carbon residue percentage in residuum from distillations. The chief value of the results of this work is that they permit comparisons of different types of crude oil, which has never before been possible.

A preliminary report covering the crude oils from the eastern fields has been issued by the bureau in mimeographed form.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 16, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1921.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership, since last report, 9.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The following gentlemen nominated by the Board of Managers were unanimously elected to honorary membership:

Prof. Charles Fabry, University of Paris, Paris, France.

Frank J. Sprague, Esq., 165 Broadway, New York, N. Y.

The standing committees for the year 1921–1922 were announced.

Mr. Charles W. Masland, Chairman of Committee on Science and the Arts, then introduced Mr. Jacob M. Spitzglass, of Chicago, Illinois, to whom had been awarded the Edward Longstreth Medal of Merit for his meter for measuring the flow of fluids. The President presented the medal and accompanying documents to Mr. Spitzglass, who thanked the Institute for the honor conferred upon him.

The paper of the evening, entitled "The Bearing of a Synthetic Dye Industry Upon Our National Welfare," was presented by Col. Marston Taylor Bogert, A.B., Ph.B., LL.D., Professor of Organic Chemistry, Columbia University, New York City. A brief outline was given of the synthetic dye industry, followed by a detailed description of the utilization of the by-products and intermediates for the production of important medicinals, explosives, incendiaries, war gases, photo-chemicals, inks, perfumes, artificial resins, etc. The impetus and encouragement which the dye industry has given to chemical research and the effect of the same upon the teaching of chemistry in our educational institutions, was considered briefly. The subject was illustrated by samples of many of the compounds manufactured and by the actual preparation upon the lecture table of a number of them.

A brief discussion followed the reading of the paper, in which Mr. Masland, Dr. Keller and Mr. Tutwiler participated.

On motion, duly seconded, the thanks of the meeting were extended to the speaker. Adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1921,

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Robert W. Lesley, Chairman
Gellert Alleman
Alfred W. Gibbs
Howard S. Graham
Marshall S. Morgan

EXECUTIVE.

E. H. Sanborn, Chairman
Charles Day
Walton Forstall
Alfred W. Gibbs
Alfred C. Harrison

INSTRUCTION.

Lawrence T. Paul, Chairman
George A. Hoadley
Harry F. Keller
Edward V. McCaffrey
James S. Rogers

SECTIONAL ARRANGEMENTS.

Harry F. Keller, Chairman
Gellert Alleman
George R. Henderson
Robert W. Lesley
C. C. Tutwiler

ENDOWMENT.

Coleman Sellers, Jr., Chairman
G. H. Clamer
Alfred C. Harrison
Nathan Hayward
Wm. Chattin Wetherill

EXHIBITIONS.

Benjamin Franklin, Chairman
Francis T. Chambers
Theobald F. Clark
Charles Day
Charles A. Hexamer

PUBLICATIONS.

George D. Rosengarten, Chairman
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W. C. L. Eglin
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STOCKS AND FINANCE.

Walton Forstall, Chairman
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OF THE INSTITUTE.

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H. J. M. Creighton
George S. Crampton
Clarence A. Hall
George A. Hoadley
Harry F. Keller
Marshall S. Morgan
Paul Spencer
George F. Stradling
Wm. Chattin Wetherill

MEETINGS.

Gellert Alleman
Charles Baskerville
G. H. Clamer
A. S. Cushman
George R. Henderson

MEETINGS *(Continued)*.

Joseph S. Hepburn
H. E. Ives
A. E. Kennelly
M. M. Price
George D. Rosengarten

MUSEUM.

Hugo Bilgram
Arthur L. Church
Henry F. Colvin
Charles Day
George A. Hoadley
C. W. Masland
A. E. Outerbridge, Jr.
H. H. Quimby
Charles Penrose
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 2, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1921.

MR. CHARLES PENROSE *in the Chair.*

Mr. Charles W. Masland was unanimously elected Chairman for the year 1921.

The following report was presented for First Reading:

No. 2761: Greaves-Etchells Electric Arc Furnace. This case was referred back to the Sub-Committee.

The following reports were presented for Final Action:

No. 2750: Tate Waterproofing Process,

No. 2770, No. 2771 and No. 2772: Literature, Consideration of articles published in the JOURNAL for the year 1920.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 27, 1921, at 8 o'clock, Dr. Harry F. Keller in the Chair. The minutes of the previous meeting were read and approved.

Mr. James O. Lewis, of Marietta, Ohio, Petroleum Engineer, Consulting Engineer to the U. S. Bureau of Mines, and formerly in charge of the petroleum work of the Bureau of Mines, presented a communication on "America's Petroleum Problem." An outline was given of the American petroleum industry. The sources of domestic supply and the total crude oil supply of the world were discussed. The lecture concluded with an account of the various ways in which the domestic supply may be so increased as to meet the growing demand. Lantern slides were used to illustrate the lecture.

The communication was discussed at length; a vote of thanks was extended to Mr. Lewis; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 3, 1921, with Dr. George A. Hoadley in the Chair.

Louis Cohen, Ph.D., Consulting Engineer, Washington, D. C., and Major J. O. Mauborgne, Office of the Chief Signal Officer, Washington, D. C., presented a communication entitled, "A New Method for the Reception of Radio Signals, Eliminating Static and Interference." The general problem of radio-receiving

circuits from the standpoint of selectivity was considered and a résumé was presented of previous efforts in the design of radio-receiving circuits to secure freedom from interferences. A description was given of a new type of circuits for receiving radio signals, recently developed by the speakers, making use of resonance wave coils, which effects a great reduction in interferences, either that of nearby stations or of static disturbances. The subject was illustrated by lantern slides.

After a brief discussion the thanks of the meeting were extended to the speakers.

Adjourned.

R. B. OWENS,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 10, 1921, at 8 o'clock. The meeting was called to order by Mr. Coleman Sellers, Jr.

Mr. Frank S. Clark, Mechanical Engineer, Stone and Webster, Inc., Boston, Mass., presented a communication entitled, "Modern Steam Power Station Design." A brief outline was given of the development of the art of power-station design corresponding with the progress in the design and construction of station equipment, and the points to be observed in order to secure reliability of service by proper selection, arrangement and installation of equipment were discussed. Consideration was also given to the various factors affecting the choice of design and sizes of units, such as character of service, peak load, load factor (annual and daily), growth of load, probable ultimate capacity and local topographical and other conditions peculiar to the available sites. The economy of station operation and its attainment by the working out of the proper heat balance, the selection of the operating steam pressure and temperature, the fuel to be used and the simplicity and compactness of the arrangement were discussed in detail. The paper was illustrated by lantern slides.

After a discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 9, 1921.)

RESIDENT.

MR. BEAUVEAU BORIE, JR., 135 South 18th Street, Philadelphia, Pennsylvania.
DR. HENRY M. CHANCE, 839 Drexel Building, Philadelphia, Pennsylvania.
DR. C. E. FERREE, Bryn Mawr College, Bryn Mawr, Pennsylvania.
MR. GEORGE E. KINNIER, 20 Red Bank Avenue, Woodbury, New Jersey.

NON-RESIDENT.

DR. LOUIS W. AUSTIN, Naval Research Laboratory, Bureau of Standards, Washington, D. C.

MR. WM. ARTHUR COWAN, 129 York Street, Brooklyn, New York.
MR. FREDERICK S. DELLENBAUGH, JR., 91 Spooner Road, Chestnut Hill, Massachusetts.
DR. EUGENE L. MAINES, Ellis Hotel, Chattanooga, Tennessee.

ASSOCIATE.

MR. ARTHUR W. BINNS, 1929 Poplar Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. JOHN C. BULLITT, 3RD, 1811 Walnut Street, Philadelphia, Pennsylvania.
MR. ALBERT LADD COLBY, 447 Brighton Street, Bethlehem, Pennsylvania.
PROF. CHARLES FABRY, University of Paris, 1, rue Victor-Cousin, Paris (5e), France.
MR. C. E. FOSTER, 1826 Spruce Street, Philadelphia, Pennsylvania.
DR. ENOCH KARRER, Nela Research Laboratory, Nela Park, Cleveland, Ohio.
MR. E. E. KELLER, 717 Mt. Hope Avenue, Rochester, New York.
MR. HAROLD T. MAITLAND, Sharon Hill, Pennsylvania.
MR. H. CONRAD MEYER, 203 East Willow Grove Avenue, Chestnut Hill, Pennsylvania.
DR. WM. H. NICHOLS, The Allied Chemical and Dye Corporation, 61 Broadway, New York City, New York.
MR. CARL D. ULMER, Minnesota By-Product Coke Company, 1000 Hamline Avenue, St. Paul, Minnesota.

NECROLOGY.

Mr. Frank Firmstone, Easton, Pennsylvania.

Thomas D. Mowlds, Esq., 1001 Chestnut Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

CAYLEY, A.—Collected Mathematical Papers. Vols. 2 to 13.
DALBY, W. E.—Steam Power. 1920.
DENNIS, L. M.—Gas Analysis. 1920.
EINSTEIN, A.—Relativity. 1920.
FALK, K. G.—Chemical Reactions. 1920.
GRABAU, A. W.—Geology of the Non-Metallic Mineral Deposits. 1920.
LOVETT, W. J.—Applied Naval Architecture. 1920.
MCKAY, G. L., AND C. LARSEN.—Principles and Practice of Butter Making. No date.
POYNTING, J. H.—Collected Scientific Papers. 1889.
STOCKING, W. A.—Manual of Milk Products. 1919.
VAN SLYKE, L. L.—Modern Methods of Testing Milk. 1920.

GIFTS.

Allied Machinery Company, Catalogue Describing Drilling Machines. New York City, New York, 1920. (From the Company.)

Alpha Electric Company, Incorporated, Catalogue No. 20. New York City, New York, 1920. (From the Company.)

Alpha Portland Cement Company, Alpha Aids. Easton, Pennsylvania, 1920. (From the Company.)

Anderson Brothers Manufacturing Company, Anderson Pneumatic Scraper. Rockford, Illinois, 1920. (From the Company.)

Anderson Electric and Equipment Company, Catalogue No. 3. Chicago, Illinois, 1920. (From the Company.)

Armstrong Machine Works, Catalogue C. Three Rivers, Michigan, 1920. (From the Works.)

Automatic Fuel Saving Company, Fuel Saving Device and Gray System Results. Boston, Massachusetts, 1920. (From the Company.)

Ball Engine Company, Bulletins Nos. S–16, S–22, S–30, S–36. Erie Pennsylvania, 1920. (From the Company.)

Bartlett and Snow Company, Bulletin No. 45. Cleveland, Ohio, 1920. (From the Company.)

Boiler Kote Company, The Boiler Kote Method. Chicago, Illinois, 1920. (From the Company.)

Bristol Company, Bulletins Nos. 303–291. Waterbury, Connecticut, 1920. (From the Company.)

Brown Portable Conveying Machinery Company, Bulletin No. 30. Chicago, Illinois, 1920. (From the Company.)

Brown and Shape Manufacturing Company, Catalogue No. 137. Providence, Rhode Island, 1920. (From the Company.)

Brown-Wales Company, Catalogue on Structural Material, Sheets and Plates. Boston, Massachusetts, 1920. (From the Company.)

Buffalo Forge Company, Fan System of Heating, Ventilating and Humidifying, and Standard Pipe Coil Heaters. Buffalo, New York, 1920. (From the Company.)

Canton Foundry and Machine Company, Canton Alligator Shears, Portable Floor Crane and Hoist. Canton, Ohio, 1920. (From the Company.)

Case School of Applied Science, Catalogue for 1920–1921. Cleveland, Ohio, 1920. (From the School.)

Cincinnati Planer Company, Treatise on Planers. Cincinnati, Ohio, 1920. (From the Company.)

Chicago Belting Company, Leather Packings and Specialties. Chicago, Illinois, 1920. (From the Company.)

Chicago Pneumatic Tool Company, Bulletin No. 389. Chicago, Illinois, 1920. (From the Company.)

Chrobaltic Tool Company, Chrobaltic High Speed Cutters. Chicago, Illinois, 1920. (From the Company.)

Columbia Hardware Company, Catalogue No. 1901–A. Cleveland, Ohio, 1920. (From the Company.)

Cooper Hewitt Electric Company, Studies in the Economics of Lighting. Hoboken, New Jersey, 1920. (From the Company.)

Cooper Union, Sixth Annual Report for 1919. New York City, New York, 1920. (From the Cooper Union.)

Crouse Hinds Company, Bulletin No. 1000 R. Syracuse, New York, 1920. (From the Company.)

Cutler-Hammer Manufacturing Company, Motor Control Apparatus. Milwaukee, Wisconsin, 1920. (From the Company.)

De Laval Steam Turbine Company, Bulletin S, Centrifugal Pumps for Sugar House Service. Trenton, New Jersey, 1920. (From the Company.)

Electric Furnace Company, Booklet 9-B. Salem, Ohio, 1920. (From the Company.)

Engineer Company, Modern Practice in Combustion Control. New York City, New York, 1920. (From the Company.)

Engineers School, Sound Ranging and Military Mining. Washington, District of Columbia, 1920. (From the School.)

Eureka Battery Company, Catalogue No. 10. Chicago, Illinois, 1920. (From the Company.)

Foster Marine Boiler Corporation, Catalogue No. 51. New York City, New York, 1920. (From the Corporation.)

General Electric Company, Life in a Large Manufacturing Plant. Schenectady, New York, 1920. (From the Company.)

General Radio Company, Bulletins of Electrical and Radio Laboratory Apparatus. Cambridge, Massachusetts, 1920. (From the Company.)

Graver Corporation, Reap as the Harvester. East Chicago, Illinois, 1920. (From the Corporation.)

Greenfield Tap and Die Corporation, Catalogues Nos, 40, 41, 42, 43. Greenfield, Massachusetts, 1920. (From the Corporation.)

Griscom-Russell Company, Leaflet No. 6, and Bulletins Nos. 225, 240, 231, 230, 228, 311, 1010, 902, 250, 1140, 1110, 1106, 1120. Philadelphia, Pennsylvania, 1920. (From the Company.)

Haiss Manufacturing Company, Incorporated, Booklet No. 820. New York City, New York, 1920. (From the Company.)

Hoadley, George A., Monograph on Illumination. Philadelphia, Pennsylvania, 1920. (From Dr. Geo. A. Hoadley.)

Lamson Company, Lamson Pneumatic Tubes for Conveying Papers and Merchandise. Boston, Massachusetts, 1920. (From the Company.)

Leeds and Northrup Company, A Method of Recording Blast Furnace Temperatures, 1920. (From the Company.)

Link-Belt Company, Booklet on Traveling Water Screens, Books Nos. 375 and 380. Chicago, Illinois, 1920. (From the Company.)

Little, Authur D., Incorporated, The Petroleum Outlook. Cambridge, Massachusetts, 1920. (From the Corporation.)

Living-Stone Company, Catalogue of Products of Living Stone and Litholex. Baltimore, Maryland, 1920. (From the Company.)

Locomotive Superheater Company, Bulletin No. T.-5. New York City, New York, 1920. (From the Company.)

Massachusetts Board of Water Commissioners, Annual Report for the Year Ending March 31, 1919. Cambridge, Massachusetts, 1920. (From the Commissioners.)

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Moore Shipbuilding Company, Booklet. Oakland, California, 1920. (From the Company.)

National Carbon Company, Incorporated, The Carbon Electrode. New York City, New York, 1920. (From the Company.)

National Tool Company, Catalogue E. Cleveland, Ohio, 1920. (From the Company.)

Nebraska State Railway Commission, Twelfth Annual Report for 1919. Nebraska, 1920. (From the Commission.)

New Jersey Department of Conservation and Development, Bulletin No. 20. Trenton, New Jersey, 1920. (From the Department.)

Newton Machine Tool Works, Inc., Bulletin Nos. 54–55. Philadelphia, Pennsylvania, 1920. (From the Works.)

New York Public Service Commission, Second District, Thirteenth Annual Report for the Year 1919. Albany, New York, 1920. (From the Public Service Commission.)

Ohio Brass Company, Electric Arc-Welding. Mansfield, Ohio, 1920. (From the Company.)

Ontario Department of Mines, Twenty-ninth Annual Report, Part vi. Toronto, Canada, 1920. (From the Department.)

Pennsylvania Forge Company, Catalogue No. 3. Bridesburg, Pennsylvania, 1920. (From the Company.)

Philadelphia Department of City Transit, Annual Reports for the Years of 1917, 1918 and 1919. Philadelphia, Pennsylvania, 1920. (From the Department.)

Philadelphia Municipal Court, Report 1919; Chilton Automobile Directory, January, 1918, and 1919. (From Mr. Chas. A. Duryea.)

Philip Carey Company, Catalogue No. 1362. Lockland, Cincinnati, Ohio, 1920. (From the Company.)

Princeton University Observatory, Contributions No. 5, The Eclipsing Variable U Cephei. Princeton, New Jersey, 1920. (From the University.)

Pyrolectric Instrument Company, Pyrolectric Bi-monthly Bulletin No. 14, 1920. Trenton, New Jersey. (From the Company.)

Reading Iron Company, Bulletin No. 1. Reading, Pennsylvania, 1920. (From the Company.)

Robinson Connector Company, Booklet on the Robinson Connector. New York City, New York, 1920. (From the Company,)

Scott Valve Manufacturing Company, Catalogue No. 12. Detroit, Michigan, 1920. (From the Company.)

Shope Brick Company, Shope Concrete Brick. Portland, Oregon, 1920. (From the Company.)

Smith Gas Engineering Company, Bulletins Nos. 12, 12A, 16, 11. Dayton, Ohio, 1920. (From the Company.)

Sprague Electric Works, Bulletin No. 48,961. New York City, New York, 1920. (From the Works.)

Tyler, W. S., Company, Catalogues Nos. 42 and 50. Cleveland, Ohio, 1920. (From the Company.)

United States Council of National Defense, Fourth Annual Report for the Year Ending June 30, 1920. Washington, District of Columbia, 1920. (From the Council.)

United States Radiator Corporation, The Complete Line. Detroit, Michigan, 1920. (From the Corporation.)

Van Dorn Electric Tool Company, Bulletin on Improved Heavy Duty Ball-Bearing Electric Grinders and Buffers. Cleveland, Ohio, 1920. (From the Company.)

Vassar College, Fifty-sixth Annual Catalogue, 1920–1921. Poughkeepsie, New York, 1920. (From the College.)

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Whiting Foundry Equipment Company, Foundries and Their Complete Equipment. Harvey, Illinois, 1920. (From the Company.)

Wilmington Board of Water Commissioners, Forty-ninth and Fiftieth Annual Reports, 1917, 1918–1919. Wilmington, Delaware, 1920. (From the Commissioners.)

Wood, Wm. H., Loco Fire Box and Tube Plate Company, Economics in Railroad Problems. Media, Pennsylvania, 1920. (From Mr. William H. Wood.)

BOOK NOTICES.

INTRODUCTION TO GENERAL CHEMISTRY. An Exposition of the Principles of Modern Chemistry, by H. Coupaux, Professor of Mineral Chemistry at the School of Industrial Physics and Chemistry of the City of Paris. Translated by Henry Leffmann, A.M., M.D. 195 pages, with 30 illustrations. P. Blakiston's Son and Co., Philadelphia, 1920. $2.00.

In the author's preface it is stated that Van't Hoff once asserted that he had not understood Avogadro's postulate until it became his duty to teach it. It may be possible that the owners of less brilliant minds than that of Van't Hoff would confess having made the same observation in their own experiences, particularly in these times, when the simplest equation of former days is accompanied by a mathematical formula or two.

The physicists are taking all the joy out of life for the chemists, and as a rule are several squares above them in the graph of mathematical accomplishment, but in this case honors are even, for it doesn't seem to be possible to increase the viscosity of an elementary work to any higher degree without clogging the mental processes of the student.

The chapter headings are indicative of the scope of the work, and are as follows:

1. The Idea of the Element. The Law of Conservation of Matter.
2. Laws of Chemical Combination.
3. Atomic Theory. Chemical Formulas.
4. General Characters and Interrelations of the Elements.
5. Properties and Theory of Solutions.
6. Chemical Affinity.
7. Thermo-Chemistry.

The subject, it will be seen, is developed gradually and logically along orthodox lines of arrangement. Each principle, axiom or law, is well illustrated by examples, and exceptions are noted where these are of importance.

One of the most valuable chapters is that on the General Characters and Interrelations of the Elements, for here are discussed some of the most modern conceptions of chemistry as regards valence, electrochemistry, spectroscopy, radioactivity, isotopy and atomic structure.

The other chapters are equally interesting and valuable, but none contains so much that is essentially new.

The chapter on Solutions is particularly well handled, especially in the matter of illustrations, which are numerous and well chosen for their clarifying effect.

The language is smooth and free from idioms, and the translator is to be congratulated upon having made such an important book available to English-speaking chemists.

The book will be a welcome addition to the library of every teacher of chemistry, and will aid advanced students in a material degree to comprehend chemical theory and acquire proper conception of the intimate relation between chemistry and physics.

C. H. LAWALL.

PENROSE'S ANNUAL. The process Year Book. Quarto, 84 pages, many illustrations, plain and colored. Tennant and Ward, New York City. $5.00 net, postpaid.

This is the issue of the 23rd year of this well-known compilation and record of progress in the higher departments of printing. In addition to a large number of full-page illustrations, most of which are in color, interesting and valuable essays are given, among which are to be noted a suggestion for a new method of color photography, an improved method of measuring color, and a new method of sensitizing with dichromate. The latter topic is of special interest in photographic chemistry, and some of the points of the paper may be given here. Originally written in Italian by Professor Namias, it is translated by R. Born. The rules of chemical nomenclature are not followed, but this is usual in the contributions of photographers. Namias starts by pointing out that paper prepared with neutral chromates has a low sensitiveness, and that addition of alkali-carbonates reduces this, and caustic alkalies reduces it still more. In fact, by adding large amounts of these substances the sensitiveness can be destroyed. On the other hand, the keeping qualities are improved by such additions, so that while a paper sensitized with dichromate will keep a day or so only, one containing the neutral chromate will keep for several days. The plan suggested is to prepare the paper with the neutral chromate with addition of alkali-carbonate, and then, when it is to be used, fume it with acetic acid. This fuming is done in a manner similar to that used in fuming silver paper with ammonia. The acid produces a certain amount of dichromate, and the paper acquires much greater sensitiveness. The author thinks that this process can be applied to the production of commercial paper.

It is impossible to give in a review an idea of the beauty of the book. Its

numerous and striking color pictures must be seen to be appreciated. The paper, printing and general make-up are delightful sights in comparison with most of the printed matter of to-day.

HENRY LEFFMANN.

FRENCH-ENGLISH MEDICAL DICTIONARY. By Alfred Gordon, A.M., M.D. 8vo, 161 pages. P. Blakiston's Son and Co., Philadelphia. $3.50 net.

The value of a dictionary will depend on the care with which the words are selected so as to cover all terms within the scope of the book. In addition, bilingual dictionaries must provide some system of indicating pronunciation. No two languages of importance present more difficulties in this respect than English and French. Most of the others are fairly phonetic, and the spelling gives some clue to the pronunciation. It is true that the Italian has an awkward trick of changing the spelling for the sake of euphony, but the dominance of euphony is not as absolute as in French. It is hard to say which of the two, English or French, is the worse in its orthoepy. English has the advantage of a much simpler grammar. It has got rid of the absurd system of attaching genders to inanimate objects, and its verb-forms have been reduced to almost the lowest terms of simplicity. Neither of these modifications has taken from the language any power of expression or caused any sacrifice of clearness.

Doctor Gordon has provided an elaborate system of indicating pronunciation, the efficiency of which can only be determined by trial with beginners. It is to be regretted that scholars have not as yet agreed upon an international series of symbols for indicating all sounds in the important languages. Such systems have been suggested but not generally adopted. The statement that French words of more than one syllable are accented on the last syllable may lead to misunderstanding, for the last *written* syllable in many verb-forms is silent.

One fault common to bilingual dictionaries is the inclusion of many words that do not need definition, being so similar in form in both languages. The present work is not free from this stuffing. Opening at random at page 73, one finds a score at least of words of this class. It is true that in such works the difficulty is to determine what not to put in. The book will be of service to those who wish to read French medical contributions in the original.

HENRY LEFFMANN.

THE MICROANALYSIS OF POWDERED DRUGS. By Albert Schneider, M.D., Ph.D., Professor of Pharmacognosy in the College of Pharmacy and of Pharmacology in the College of Medicine, University of Nebraska. Second edition, 8vo, 543 pages, contents, index and 237 illustrations. Philadelphia, P. Blakiston's Son and Co. $5.00 net.

This excellently printed volume contains illustrations of the tissues of all important crude drugs, mostly, of course, from the vegetable kingdom. They have all been drawn free-hand and are, therefore, often somewhat more distinct and characteristic than will be found in practical examinations; at least that is the experience of the present reviewer in his own use of such manuals. The author deserves credit for his care and patience in making the drawings, and every page of the book shows extensive familiarity with the subject in hand. It is, however, worth considering whether, in these days of high perfection of

photomicrography and photogravure, it will not be better to use such methods for illustrations than that of free-hand drawing from the microscopic field. The procedure would, of course, scrap a good many cuts, but would be in the long run cheaper and more satisfactory.

A reference is made to photographic work in this field (wrongly designated microphotography) by the late Professor Maisch, which it is stated was not a success, but photographic methods and optical appliances have been greatly improved since that time.

Another point is the waste of space in the arrangement of the illustrations and the appropriate legends. Considering the high cost of paper, a more condensed arrangement should be used. In most cases the legend could be placed in small type on the same page with the drawing, but it is always placed on a facing page, so that, for instance, in the description of aloes, two pages are taken up when a single one would not only be sufficient but really make a neater and more serviceable form. No statement appears on the illustrations or descriptions as to the degree of magnification.

In the preliminary text, a good deal of valuable and interesting information is given as to the bearings of the U. S. P. standards, and of the difficulties in establishing standards that will be adapted to the conditions of trade and manufacture, and at the same time protect the consumer from inferior articles. The dangers to drugs from the different types of parasites are set forth fully and clearly. In connection with the description of microscope technic, some account of the early history of the instrument is given. In a general statement as to the bibliography, Doctor Schneider expresses the opinion that the important literature is to be found almost exclusively in German and French. The data of the book indicate that with the later developments in microscopic work, especially the application of polarizing and other optical accessories, and of processes of microanalysis, much valuable addition to the equipment for detecting adulteration and inferiority in drugs will be obtained. Meanwhile, this work will be at the service of both student and practical worker.

HENRY LEFFMANN.

TREATISE ON GENERAL AND INDUSTRIAL ORGANIC CHEMISTRY. By Ettore Molinari, Professor of Industrial Chemistry at the Royal Milan Polytechnic. Translated by Thomas H. Pope, B.Sc., A.C.G.I., F.I.C. Part 1, 8vo, 441 pages, contents, index and 254 illustrations. Philadelphia, P. Blakiston's Son and Company. $8.00 net.

Molinari's books have had great success, not only in the country of their publication, but by translation into English, French and Spanish. They contain a very large amount of information on both practical and theoretical questions, and, in addition, discussions of some of the sociologic bearings of the chemical industries. It is a matter of some astonishment that an Italian authority should be able to command so much interest among the chemical industries of nations such as the United States, England and France, in which these industries have been so extensively developed. The world has been for many centuries looking to Italy for art, art objects, music and certain types of literature, but its influence in the field of chemistry has not been so striking. It is

true that in physics the discoveries of Volta, Galileo, Melloni and the Florentine academicians are familiar.

The present work is translated from the third Italian edition. The practical part, which is preceded by thirty pages of general and theoretical chemistry, begins with a consideration of the aliphatic hydrocarbons, and follows the usual evolution to the more complex alcoholic and acidic derivatives, with their related forms. The closing pages of the book are devoted to compounds containing sulphur and nitrogen. The last section, under the somewhat striking title of "Derivatives of Carbonic Acid," takes up the technology of uric acid, caffeine and other substances of the purin class.

The general character of the work was presented in the review of the first edition and need not be repeated here, as the arrangement and contents of the text are essentially the same. The reviewer had occasion to express his opinion that much of the matter on the principles of chemistry is out of place in such a work, and in these days, when book-making is so expensive, authors should bear in mind that "Brevity is the soul of wit." In connection with the technology of ethyl alcohol, a large amount of information is given on the use of alcohol as fuel, and on its production from other than cereals and fruits. A good deal of space is, however, practically wasted in a discussion of the sociologic and physiologic relations of alcoholic beverages. The statistical data are often interesting, but the statements of cost must be of no practical value, on account of many interfering circumstances. Thus, the statement that chloral hydrate costs 6s per kilo can only apply to a particular time and place.

The translation appears to be well done and the proofreading careful. The chemical nomenclature and the spelling of chemical terms are, of course, British, but we may be thankful that the translator has preserved the metric measures in the statement of quantities.

HENRY LEFFMANN.

PHARMACEUTICAL BOTANY. A text-book for students of pharmacy and science, by Heber W. Youngken, A.M., M.S., Ph.M., Ph.D. Professor of Botany and Pharmacognosy and Director of the Microscopical Laboratories of the Philadelphia College of Pharmacy and Science. Small 8vo, xix–411 pages, glossary, index and 238 illustrations. Third edition, revised and enlarged. Philadelphia, P. Blakiston's Son and Co. $3.75 net.

In very compact and yet fully intelligible form, neatly printed and abundantly illustrated, Professor Youngken's book will be entirely satisfactory as a guide to the pupil in the general principles of botany, as well as for the student of its applications to pharmacy and science. The text is very comprehensive, embracing not only the general principles of structural botany, but the technic of preparing, mounting and examining specimens. As illustrations of typical forms of vegetable life, the life histories of a fern (*Aspidium felix-mas*), of a gymnosperm (*Pinus strobus*) and of an angiosperm (*Erythronium Americanum*) are treated in detail and abundantly illustrated. The cell life of the plant is then taken up, attention being given to the starches, carbohydrates, oils, resins and proteins, with the other ingredients.

An interesting chapter is that on botanical nomenclature, in which the principles of the binomial nomenclature are explained, and also the system of double

authorities, which are so puzzling to the beginner. As an illustration of this system, Doctor Youngken gives the name of purging cassia, *Cathartocarpus Fistula* (Linné) Persoon, quoting from National Formulary IV. The reviewer is compelled to say that if the N. F. really uses the name Linné in connection with the plant, it is to be regretted, for botanists have universally agreed that the name of the great founder of the binomial system should be abbreviated to L.

There is an enormous amount of information in the book, and the abundance of excellent illustrations, the good type and good paper make it a most serviceable manual on the topic to which it is devoted. The style is clear, and the text is entertaining reading as well as instructive.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 95, Diagrams of Aeroplane Stability. 25 pages, diagrams. Washington, Government Printing Office, 1920. A study of the effect on longitudinal and lateral oscillations of an airplane of simultaneous variations in two resistance derivatives while the remainder of the derivatives are constant. The results are represented by diagrams in which the two variable resistance derivatives are used as coördinates, and curves are plotted along which the modulus of decay of a long oscillation has a constant value. The same type of analysis is also carried out for the stability of the parachute. In discussing the stability of a helicopter it is concluded that the gyroscopic effect on stability will be greater than in the case of the aeroplane.

Report No. 98. Design of Wind Tunnels and Wind-Tunnel Propellers, II. 10 pages, illustrations, plates, diagrams, quarto. Washington, Government Printing Office, 1921. The variations in velocity and direction of the wind stream were studied by means of a recording air-speed meter and a recording yawmeter. The work was carried on both in a one-foot diameter model tunnel and in a five-foot, full-sized tunnel, and wherever possible comparison was made between them. It was found that placing radial vanes directly before the propeller in the exit cone increased the efficiency of the tunnel to a considerable extent and also gave a steadier flow. The placing of a honeycomb at the mouth of the experimental portion was of the greatest aid in straightening the air flow, but at the same time this decreased the efficiency of the tunnel. Several types of diffuser were tried in the return air stream, but only a slight improvement resulted in the steadiness of the flow. Some experiments were tried on the effect of the shape of exit cone, and it was found that a straight cone in all cases gave the highest efficiency. The effect of placing a closed room about the model tunnel of the same proportional size as the building on the five-foot tunnel decreased the speed for the same power 14½ per cent. Several spinners were placed about the propeller in the model tunnel in the hope that they would give increased efficiency and a steadier flow, but in no case was there any improvement.

Report No. 104, Torsion of Wing Trusses at Diving Speeds. 8 pages, diagrams. Washington, Government Printing Office, 1920. It is the purpose of this report to indicate what effect the distortion of a typical loaded wing truss will have upon the load distribution. The case of high angle of incidence may be dismissed immediately from consideration, as the loads on the front and rear trusses are

nearly balanced, and consequently there will be little angular distortion. A given angular distortion will have the maximum effect upon load distribution in the region of the angle of no-lift, because the slope of the lift curve is highest here, and it is here that the greatest angular distortion will occur, because the load on the front truss acts downward, while the load on the rear truss acts upward.

The RAF-15 aerofoil was chosen as most typical of present-day wing sections and serves for an illustrative example. This was combined with JN-4 wing truss, a biplane with overhanging upper wings. Starting with the assumption of a loading for a rigid structure, the wing truss and the deflections were calculated. The assumption of loading for the second trial was based upon the deflections as determined by the first trial. After several approximations it was possible to compute accurately the angular distortion at each panel point.

It was found that no great angular distortion occurred at panel points where there was adequate stagger bracing, but that it was considerable at the tip of the overhanging portion of the upper wing. In conclusion, it may be said that it is not worth the added complication to correct the load distribution on the conventional biplane for wing truss distortion, but that it would be highly advisable in the case of a monoplane, where the wires of the lift truss make an acute angle with the spars and where there can be nothing to take the place of stagger bracing. It would also be advisable in the case of the internally braced wing, where the relative deflection is likely to be high.

PUBLICATIONS RECEIVED.

The Gas World Year Book, 1921: 189 pages, quarto. London, Benn Bros., Ltd.

Exploitation du petrole par puits et galeries, par Paul de Chambrier. 106 pages, diagram, 12mo. Paris, Dunod, 1921.

U. S. Bureau of Mines: Bulletin No. 189, Bibliography of Petroleum and Allied Substances in 1918, by E. H. Burroughs. 180 pages, 8vo. Bulletin No. 191, Quality of Gasoline Marketed in the United States, by H. H. Hill and E. W. Dean. 275 pages, 8vo. Miners' Circular No. 27, Causes and Prevention of Fires and Explosions in Bituminous Coal Mines, by Edward Steidle. 75 pages, illustrations, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States, November, 1920, by W. W. Adams. 10 pages, 8vo. Technical Paper No. 255, Chlorination of Natural Gas, by G. W. Jones, V. C. Allison and M. H. Meighan. 44 pages, 8vo. Technical Paper No. 264, Preliminary Investigations of Storage-Battery Locomotives, Specifications, Laboratory Tests, Permissible Schedule, by L. C. Ilsley and H. B. Brunot. 35 pages, illustrations, plates, 8vo. Technical Paper No. 267, Stenches for Detecting Leakage of Blue-Water Gas and Natural Gas, by S. H. Katz and V. C. Allison. 22 pages, illustrations, 8vo. Technical Paper No. 275, Quarry Accidents in the United States During the Calendar Year 1919, by William W. Adams. 66 pages, diagram, 8vo. Washington, Government Printing Office, 1921.

U. S. Bureau of Standards: Technologic Paper No. 180, Causes and Prevention of the Formation of Non-condensible Gases in Ammonia Absorption Refrigeration Machines, by E. C. McKelvy, Chemist, and Aaron Isaacs, Asso-

ciate Chemist. 10 pages, plate, 8vo. Washington, Government Printing Office, 1920. Price, 5 cents.

Canada, Department of Mines, Mines Branch: Phosphate in Canada, by Hugh S. Spence, M.E. 156 pages, illustrations, plates, maps, 8vo. The Production of Iron and Steel in Canada During the Calendar Year 1919, by John McLeish, B.A. 45 pages, 8vo. Ottawa, King's Printer, 1920.

National Advisory Committee for Aeronautics: Technical Notes No. 34, The 300 H.P. Benz Aircraft Engine, by Dr. A. Heller. 10 pages, illustrations, diagrams. Technical Notes No. 35, The Optical Wing Aligning Device of the Langley Field Tunnel, by F. H. Norton and D. L. Bacon. 3 pages, illustrations. Technical Notes No. 36, N. A. C. A. Langley Field Wind Tunnel Apparatus. The Tilting Manometer, by F. H. Norton and D. L. Bacon. 3 pages, illustrations. Technical Notes No. 38, Measurements of Rudder Moments on an Airplane During Flight, by von Heidelberg. 23 pages, illustrations. Technical Paper No. 40, Effect of the Reversal of Air Flow Upon the Discharge Coefficient of Durley Orifices, by Marsden Ware. 12 pages, illustrations. Technical Notes No. 42, The Determination of Downwash, by Walter S. Diehl. 8 pages, diagrams. 6 pamphlets, quarto. Washington, 1921.

The American Glass Industry.—The *Jour. Soc. Chem. Ind.*, in the final issue for 1920, gives some interesting statements by a British chemist who recently visited the more extensive glass industries in the United States. American efforts are directed principally to the production of glassware for the sale to people at large, optical glass and that intended for decorative purposes occupying a minor place. American glass works also generally specialize somewhat narrowly, one very large corporation, which has several factories under its control, making only wide-mouthed milk bottles. Automatic machinery is largely in use, the specialization permitting the application of such machinery to a much greater extent than when a great variety of articles is made. Some of the machines are strikingly productive, one of the Edward Miller type being able to turn out 11,000 tumblers per day. An automatic machine for blowing electric-light bulbs is capable of producing 100,000 bulbs per day. Glass tubing is drawn mechanically, a very successful machine having been invented for this purpose.

All these contrivances may seem typically American. Indeed, they are, for the Americans have shown in the glass industry such ingenuity and cleverness, such freshness of ideas and patience in working them out as to provide an object lesson for the rest of the world.

In conclusion, it may be said that on the actual glass-making side also development is becoming active largely through the work of scientific investigators. It is sufficient to refer to the development of really good selenium red glass, to the " day-light " lamp, and to Pyrex glassware and other glassware for cooking purposes.

H. L.

CURRENT TOPICS.

The Fuel Oil Problem.—This problem continues to attract attention from both the industrial and diplomatic point of view. Among the latest contributions to the former phase is a paper by W. A. WHITE, read before the Northeast Coast Institution of Engineers and Shipbuilders, at Newcastle-upon-Tyne. Advance sheets of this paper have just been received.

After some allusion to the ancient use of bitumens and petroleums, and a discussion of the theories of origin, the author gives an account of the methods of obtaining them, stating that the discovery of their location is becoming more and more a science, as a result of geologic study. Interesting accounts are given of some of the great "gushers." In one of the Mexican wells, the drill weighing two tons was shot out of the well to a great height and landed forty-one yards from the well, almost at the feet of a photographer. This well yielded at one time 260,000 barrels in twenty-four hours.

The world's actual production in 1920 was about 700,000,000 barrels, of which Mexico produced 155,000,000 and the United States 445,000,000. Mr. White states that the potential capacity of Mexico, by which he means the amount that could be obtained by thorough exploitation, was, for 1920, 747,000,000 barrels. The average production in Mexico for that year was 1000 barrels a day for each well. There are twenty-five wells in Mexico that will flow 24,000 barrels per day, a total of 600,000 barrels. The known oil regions of Mexico are divided into three areas.

Many tables are given showing ratios of increase and other data. The total world deposits of petroleum are estimated at a little over forty-three thousand million barrels, which amount is about equally distributed in the two hemispheres. There are much larger deposits north of the equator than south, but this may be due partly to the greater land area in the former. No estimate can be made as to what may be under the sea.

The first tank steamer was built in England in 1885, presumably for German owners, though that is not stated, for it was called the *Glück auf*. It was 300 feet long and could steam at about 11 knots. The writer of this abstract had occasion to board this vessel as quarantine officer when it arrived at the port of Philadelphia. The United States and Great Britain, now the principal owners of tank steamers, owning respectively 41 per cent. and 40 per cent., the next largest being Holland with 3 per cent. The tonnage, however, under the stars and stripes is much greater than that under the British flag. A notable proportion of the American tonnage is under sail.

A large amount of information is given as to the method of obtain-

ing, transporting, and storing oil, and some data in regard to testing it.

Although the United States is producing at present about two-thirds of the world output, yet over 100,000,000 barrels were imported to meet the consumption. In this fact lies the importance of the oil question to the United States.

H. L.

German Chemical Publications.—A drastic change in the mode of issue of the *Zeitschrift für angewandte Chemie* has been decided upon for 1921. Hitherto that journal—now coming into its thirty-fourth year—has consisted of three parts with separate pagination: (1) An "Aufsatzteil," containing original articles; (2) a "Wirtschaftlicher Teil," or economic section; and (3) the technical portion of the *Chemisches Zentralblatt*. These parts were issued twice weekly, as follows: (1), (2), and (3) were issued together at 200 mk. yearly, (2) at 50 mk., and (1) and (2) together at 120 mk. Partly on account of excessive cost and partly because the division of the abstracts into "pure" and "applied" was found to be unsatisfactory, it has been decided to discontinue the separate issue of the technical portion of the *Zentralblatt*, but all members of the Verein Deutscher Chemiker will be allowed to subscribe for the entire *Zentralblatt* at the same subscription rate, *viz.*; 200 marks, that is asked of members of the German Chemical Society, the price to non-members of these societies being 1000 mk. It is stated that the price of 200 mk. does not cover one-half of the cost of production and distribution, the deficit being made good by the Adolf Baeyer Society.

The *Z. für angewandte Chemie* will therefore in future consist of two parts only, an "Aufsatzteil," which will be modified to include reviews of progress in the different branches of pure and applied chemistry, and an economic portion, consisting of the existing publication *Die Chemische Industrie*, to be issued as a weekly supplement. The subscription price for the *Zeitschrift*, together with postage, etc., has been fixed at 56s. for England and colonies, $11.20 for the United States, and 127 fr. for France. (*J. S. C. I.*, 1920.)

In this connection it may be noted that a similar merging in the field of physics has taken place, the *Fortschritte der Physik, Halbmonatliches Literatur-verzeichnis*, and the *Beiblätter zu den Annalen der Physik* having been combined under the title *Physikalische Berichte*, issued under the joint auspices of the Deutsche Physikalische Gesellschaft and the Deutsche Gesellschaft für technische Physik. Twenty-four parts are to appear during the year, and the issues for 1920 are considered the first year, there being apparently no volume designation. The yearly subscription is fixed at 80 marks.

H. L.

The German Potash Industry.—At a meeting of the German Potash Syndicate held on October 14th it was stated that the convention prices made during the war had been renewed for 1921.

Production during the period January-September was 800,000 metric tons of pure potash (K_2O), an increase of 160,000 t. over

the previous year; the increase was mainly due to the large agricultural demand in January and February last. Production costs have more than doubled, and the profit is barely above that for 1919. Although prices have not been raised since December, 1919, trade has been slack since May, except with adjacent countries, and the market in eastern Europe was at a standstill. The prohibition of the export of potash to Poland has closed a market which prior to the war consumed over 100,000 t. (K_2O) per annum. No decrease in the price of potash salts for agricultural purposes is probable, as the cost of production is still rising. (*J. S. C. I.*, 1920.)

H. L.

Radiation in Explosions of Hydrogen and Air. W. T. DAVID. (*Proc. Royal Soc.*, A690.)—A Hopkinson optical indicator was used to throw a spot of light on a revolving photographic film. From this record the temperature of the mixture at the time of explosion and during the subsequent period of cooling could be deduced. On the same film was the trace of a light-spot controlled by a platinum bolometer which received radiation from the gaseous mixture. This method makes it possible to follow continuously the changes that occur in a violent explosion. In the case of a "25.4 per cent. mixture of hydrogen and air" the temperature 0.17 second after explosion was found to be 2400° C. abs., and up to that time the total loss of heat by radiation was only .5 per cent. of the heat of combustion; at the end of .1 second, the corresponding quantities are 1920° C. and 7.7 per cent., and at the end of a whole second, 810° C. and 16.1 per cent. The proportion of heat lost by radiation decreases greatly as the strength of the mixture is weakened.

This paper is one of an extensive series of investigations being made in Great Britain upon the various phases of gaseous ignition.

G. F. S.

On the Use of "Vacuum Arcs" for Interferometry. J. GUILD, National Physical Laboratory. (*Proc. Phys. Soc. London*, vol. xxxii, p. 341.)—In the testing of the parallelism of the sides of slabs of optical glass it is often necessary to obtain interference between rays of light that have passed over quite different distances. In order that this may take place the light used must be monochromatic, and not only that but the line of light employed must be very narrow. Lately the green line of 5461A.U. proceeding from the mercury vapor lamp has been largely used. It is, however, found that the various types of this lamp are by no means equally good when the difference of path of the interfering light is large. The very bright, short lamps are not satisfactory, because they get hot, the pressure within them rises and the lines are in consequence broadened. The long lamps are rather inconvenient on account of their greater size. The author has devised a short lamp that in spite of its small volume gives a sharp line. Remembering that the vapor pressure within a closed space is

governed by the temperature of the coolest part, he provides a large bulb over the positive electrode. This acts as a condensing chamber for the mercury vapor and thus keeps the pressure down. With it interference fringes are obtained with a maximum path difference in air of 10 cm.

G. F. S.

Reconstruction of Dwellings in the Devastated Regions of France. (*La Nature*, October 30, 1920.)—Data from the Ministry of the Liberated Regions.

Number of houses in the devastated zone in 1914.	1,204,862
Number of houses totally destroyed	293,733
Number of houses partly destroyed	362,755
UP TO JULY 1, 1920:	
Number of houses temporarily repaired	342,430
Number of houses completely repaired	292,470
Number of barracks built	33,454
Number of temporary wooden houses built	39,448
Number of houses built of materials harder than wood	20,645
Number of inhabitants lodged in:	
Repaired houses	645,116
Wooden barracks	126,771
Temporary wooden houses	144,189
Houses built of harder materials than wood	71,777

Thus nearly a million people are back in the devastated regions.

G. F. S.

Ostrich Eggs as Food. (*Scientific Am. M.*, December, 1920, p. 324.)—Mr. Gallichan, diet expert, who has been experimenting with ostrich eggs supplied by the New York Zoölogical Gardens, declares that the food value of the ostrich egg is about the same as that of the domestic hen's egg. The flavor is identical, and although the ostrich eggs contain less protein than meat, they have more fat and a fair amount of phosphorus and iron. One egg will make an omelet sufficient for thirty people.

Flow of Water. (*U. S. Geological Survey Press Bulletin No. 461*, December, 1920.)—"Second-foot," as defined by the Survey, is an abbreviation for cubic foot per second and is the unit for measuring the rate of discharge of water flowing in a stream 1 foot wide and 1 foot deep at a rate of 1 foot per second. It is generally used as a fundamental unit in measurements of stream flow.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area

drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

An "acre-foot" is equivalent to 43,560 cubic feet and is the quantity required to cover an acre to a depth of 1 foot. The term is commonly used in connection with the storage of water for irrigation.

A flow of 1 second-foot equals 7.48 United States gallons a second, 448.8 gallons a minute, or 646,317 gallons a day. As a California "miner's inch" equals 0.187 gallon a second, there are 40 California miner's inches in 1 second-foot.

Progress of the American Dye Industry.—The Report "Census of Dyes and Coal-tar Chemicals, 1919, Tariff Information Series, No. 22," has been recently issued and may be obtained from the Superintendent of Documents, Washington, D. C., for 20 cents. From a summary of the report, the following data are taken. The production of dyes during 1919 was equal to, and possibly in excess of, our pre-war imports, with the exception of vat-dyes other than indigo. The manufacture of these vat-dyes requires long research, high skill, and large capital. The domestic production of indigo exceeded the 1914 imports, which is one of the notable achievements of the dye industry in this country. The average prices of the dyes made in 1919 were about the same as those of 1918, but the quality had been improved so that the consumer was getting more value for outlay.

The total production of dyes in 1919 was 63,000,000 pounds, being 38 per cent. more than the pre-war imports. Certain dyes have been manufactured in excess of domestic requirements, and considerable amounts have been exported, especially to Japan and China, but it must be borne in mind that such exportation has so far met with little competition from German dyes, and also that the domestic production vat and alizarin dyes was below the domestic requirements.

With the exception of anthracene, ample supplies of coal-tar crudes are now available in this country, and some progress has been made to increasing the supply of anthracene. The securing of adequate supplies of anthracene and anthroquinone will have a very favorable action on the dye industry. A decrease in total production of intermediates is noted because of the lessened demand for explosives, but seventy-six intermediates not heretofore produced in this country were furnished during 1919. It appears that in many cases the intermediates are sold at unreasonably high prices by German firms, because their true nature is concealed by fanciful names. The report, therefore, gives the true chemical name, and composition, with the trade name. American users will now be able to purchase these materials under their proper names. Data from Germany show that the output from German factories during 1920 was about one-third the pre-war output. H. L.

Present Status of the Merchant Marine of the Greater Nations.—In a paper by MAXWELL BALLARD, presented before the North-east Coast Institution of Engineers and Shipbuilders, at a meeting at Newcastle-upon-Tyne, in December last, advance sheets of which have lately been received, a comparison is given of the present status of the principal merchant marines, compared with two previous years.

Mid Year	1909	1914	1920
World Total Sea-going Tonnage	34,467,295	43,143,436	51,786,120
	Per Cent.	Per Cent.	Per Cent.
United Kingdom	47.9	43.8	35.1
Germany	10.75	11.9	.81
U. S. A.	4.49	4.81	24.1
Norway	3.67	4.54	3.82
France	4.20	4.46	5.72
Italy	2.79	3.32	4.27
Holland	2.62	3.39	3.44
Japan	3.1	3.96	5.78

Concerning this table, Ballard remarks as follows: "The three striking features are our loss of actual tonnage and pre-eminence of position, the elimination of Germany as a shipping power and the jump into second place of the United States. In every probability Germany's complete loss of place is temporary. There are already signs of efforts of recovery which are satisfactory in that there can be no revival of world trade of any account until Central and Eastern Europe settle down to steady work and production."

Attention is, however, called to the fact that the important point, the special subject of the paper is the freight tonnage; that is, the tramp steamers or cargo carriers, which meet in competition and rule the ocean freight market. Moreover, the only vessels now of account in this competition are steel steamers and motor vessels. Eliminating all other types, the figures are:

	1914	1920
Number of vessels	15,023	17,549
Tons	24,934,831	32,518,440

The last total includes steel coasting tonnage, which it was not possible to exclude accurately. A significant remark by the British engineer is: "Our interest centres upon our own position and that of the U. S. A., the really serious competitor, since the tonnage of both countries includes 60 per cent. of the total world tonnage."

A statement issued lately by Lloyd's Register shows that the aggregate tonnage now in course of construction in Great Britain is a little over 7,000,000 tons, 51.6 of which is under construction. The United States' share of total tonnage building has fallen from 37.7 per cent. to 18.2 per cent. To-day, the United Kingdom is building more than all the rest of the world combined, a position held by the United States during the late intensified shipbuilding campaign. The following data, taken from a recent issue of the Philadelphia *Public Ledger*, will be of interest in this connection:

"The status of world shipbuilding now, as compared with a year ago, is shown by the following table of gross tons of shipping under way at the two periods:

	Dec. 31, 1919	Dec. 31, 1920
United States	2,966,000	1,310,000
United Kingdom	2,994,000	3,709,000
Other countries	1,901,000	2,160,000
World total	7,861,000	7,179,000

"This table does not include figures from Germany.

"How Great Britain has been resuming its place as the world's shipbuilder is indicated in that of the 3,709,000 tons now under construction; 1,257,000 tons is for purchasers abroad."

The same issue also reports the arrival, in Berlin, of a commission in the Harriman interest, to effect a joint agreement with the Hamburg-American Company.

H. L.

British Dye Industry.—The British Parliament has passed an act prohibiting for ten years the importation of dyes from any source. Similar action was taken by proclamation in February, 1919, but in December following the order was declared invalid by a court. The problem of protecting the British industries along this line was discussed by Herbert Levenstein in an address before the London section of the Society of Chemical Industry (*J. S. C. I.*, 1920, xxxix, T. 317). The remarks of Lord Moulton are quoted as follows: "We have had peace in England, and never thought of danger, industrial or national. Even though there may not be another war, there is perpetual war going on industrially. It is based on what in the industrial world corresponds to war in the political world." Mr. Levenstein goes on to say that in the industrial war the struggle is for control of the "key industries," just as in political war the struggle is for the control of key positions. The German Interessen Gemeinschaft (I. G.) is using every effort to recover control of the old monopoly. It is stated, incidentally, that every toxic substance used by the Germans during the war, with insignificant exceptions, was made

by the I. G. Mr. Levenstein's words as to the danger from poison gases are well worth quoting:

"So long as there is no counter to the rapid production of toxic substances in Germany, the world is not safe; the menace of the Rhine factories lies not only in their position but in the fact that they are unique. That the next war will begin as chemical war is certain." At the time of the signing of the Armistice, 70 per cent. of the casualties were due to gas.

H. L.

Microseisms. J. J. SHAW. (*Nature*, November 11, 1920.)—*Nature* now publishes from number to number brief, simple, interesting and authoritative discussions of scientific investigations and advances.

It has been known for a score of years that "no square yard of the earth's surface is ever at rest; an unending train of waves, waxing and waning in amplitude, are unceasingly coursing along the earth's crust and to unknown depths. The wave period ranges between four and eight seconds; the amplitude is between one fifty-thousandth and one two-thousandth of an inch, but with a wave-length of eight to sixteen miles. The speed of the waves is believed to be about two miles per second." Air tremors, the rocking of the observatory building in the wind and the swaying of trees, all were suggested as causes. It is now, however, known that they are real earth movements spreading over long distances.

In earthquakes the primary, the secondary phases and the long waves rising to a maximum make it possible to follow the course of the waves over the surface of the earth, but it has been difficult to identify individual microseisms. Without such identification it is impossible to study their propagation. The investigator succeeded in identifying tremors on recording instruments sixty feet apart. Emboldened by this, he extended the range until now he has two instruments two miles apart and producing records by which individual tremors can be singled out for study. The principal outcome of the studies has been to show that there seems to be no connection between the direction of the wind or any other meteorological condition and the direction in which the microseisms travel. They always arrive at the north station about .8 second before they reach the south station. It still remains to discover their origin and cause.

G. F. S.

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